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Halocarbon Refrigerant Detection Methods

by
Robert E. Tapscott and Chang W. Sohn

The Montreal Protocol and the U.S. Clean Air Act limit the production of ozone-depleting substances, including many refrigerants. Three options for cost-effectively phasing out these refrigerants from Army installations are: (1) refrigerant containment, (2) retrofit conversion to accommodate alternative refrigerant, and (3) replacement with cooling systems using alternative refrigerant. This report contributes to the first option by identifying and assessing methods to detect chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC) and hydrofluorocarbon (HFC) refrigerants that leak from air-conditioning and refrigeration systems.

As background, the report describes the relevant sections of the Montreal Protocol and the Clean Air Act, and gives an overview of refrigerants. This is followed by a description of the technologies used in refrigerant leak detection, and a survey of detector types available and their price ranges. Appendixes provide an extensive list of detector products and their specifications, plus manufacturer addresses and phone numbers.

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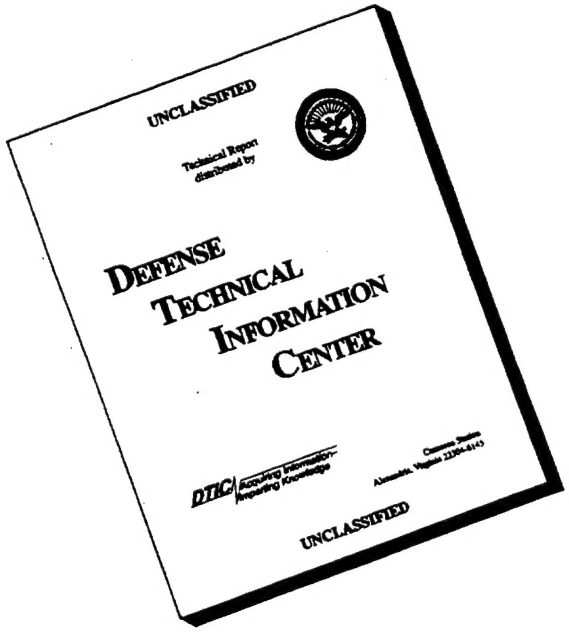

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Foreword

This study was conducted for U.S. Army Center for Public Works (USACPW) under Project 4A162784AT45, "Energy and Energy Conservation"; Work Unit XM4, "CFC Alternative Refrigerant Technologies." The technical monitor was Chris Irby, CECPW-EM.

The work was performed by the Utilities Division (UL-U) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Chang W. Sohn. Martin J. Savoie is Chief, CECER-UL-U; John T. Bandy is Operations Chief, CECER-UL; and Gary W. Schanche is Chief, CECER-UL. The USACERL technical editor was Audrey Fisher, Technical Resources.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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Background

The depletion of ozone in the earth's stratospheric layer and the identification of chlorofluorocarbon (CFC) and other halocarbon refrigerants as contributors to this depletion has resulted in both international agreement and U.S. legislation mandating a phaseout of CFC refrigerant production (Montreal Protocol; Clean Air Act Amendment of 1990). In response to these regulations, the following policy and documents have been issued:

- Department of Defense (DOD): DOD Directive 6050.9, *Chlorofluorocarbons (CFCs) and Halons* (13 February 1989)
- Headquarters, Department of the Army (HQDA): HQDA LTR 200-90-1, *Eliminating or Minimizing Atmospheric Emissions of Ozone-Depleting Substances* (27 July 1990)
- Engineering and Housing Support Center (EHSC): Technical Note 420-54-01, *Use of Chlorofluorocarbons in Air-Conditioning and Refrigeration Systems* (26 June 1991).

The U.S. Army's large inventory of air conditioning and refrigeration equipment uses a significant amount of the refrigerants scheduled for phaseout. To help the Army overcome the challenge of meeting the CFC regulatory requirements in a timely and economical manner, the U.S. Army Center for Public Works (USACPW) and the U.S. Army Construction Engineering Research Laboratories (USACERL) are working with industry to advance non-CFC refrigerant technology and to transfer this technology to the field.

In an earlier report, three (nonexclusive) options for cost-effectively phasing out CFC refrigerants from Army installations were discussed (Sohn *et al.*, 1993). These three options are: (1) refrigerant containment (conserving existing refrigerant to run systems as is, thus reducing or eliminating the need to procure additional refrigerant), (2) retrofit conversion to accommodate non-CFC refrigerant, and (3) replacement with CFC-alternative cooling systems. The present study relates to the first option.

Objective

The objective of the present study is to identify, compile, and assess methods to detect chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC), and hydrofluorocarbon (HFC) refrigerants that leak from air conditioning and refrigeration systems.

Approach

This project was executed in three phases. In Phase 1, information on commercially available sensors and equipment for CFC, HCFC, and HFC refrigerants was collected, and technologies were identified. The equipment and techniques were categorized according to sensor type and application.

In Phase 2, the various products were compared. Cost, advantages, and disadvantages of each product were assessed, including ease of use, maintenance requirements, reliability, and durability. Costs include both initial acquisition costs and a rough estimation of annual maintenance costs.

In Phase 3, all activities and results were documented in this report.

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Scope

This report discusses refrigerant detection for heating, ventilation, air-conditioning and refrigeration (HVACR) systems in fixed facilities. The detection methods may also apply to mobile systems (in vehicles), but this is not the focus of this report. CFCs used as solvents and firefighting agents are also beyond the scope of this report.

Mode of Technology Transfer

This report discusses principles of halocarbon refrigerant detection at an advanced level, serving as a source of reference for researchers in this area. In the future, the information in this report will be condensed and presented at a more general level in a Public Works Technical Bulletin (PWTB) for Army installation engineers and technicians to be published and distributed through the Army Center for Public Works (USACPW), Alexandria, VA..

Metric Conversion Factors

U.S. standard units of measure are used throughout this report. A table of metric conversion factors is presented below.

1 ft	=	0.305 m
1 in.	=	25.4 mm
1 lb	=	0.453 kg
1 oz	=	28.34 g
1 cfm^3	=	0.472 1/sec

2 Background Information

Nomenclature

This report evaluates equipment and technologies used for detection of halocarbon refrigerants. The halocarbons of interest here are chemical compounds containing carbon (C) plus chlorine (Cl) and/or fluorine (F). Some halocarbon refrigerants, particularly newer ones, also contain hydrogen (H). Compounds containing bromine and iodine are also halocarbons, but as they are infrequently used as refrigerants, they are not discussed here.

Refrigerants are usually named using the refrigerant or halocarbon number but in some cases chemical formulas or chemical names are used. Below, we start with a discussion of the chemical formulas and names and proceed to the more common refrigerant naming method.

IUPAC Nomenclature

The International Union of Pure and Applied Chemistry (IUPAC) has developed rules for naming chemical compounds, including those used as refrigerants. Below is a quick overview of these rules as they apply to halocarbon compounds used as refrigerants.

All halocarbon refrigerant chemicals contain a skeleton of one or more carbon (C) atoms connected together. The compounds are named according to how many carbon atoms are present. The common refrigerants in use today contain either one carbon atom (these have names ending in "-methane") or two carbon atoms (these have names ending in "-ethane"). Some of the new chemical candidates for refrigerants, however, contain three carbon atoms (these have names ending in "-propane"). Halocarbon refrigerants have fluorine and/or chlorine atoms attached to the carbon skeleton. Atoms attached to the carbon backbone are termed "substituents." As noted earlier, hydrogen atoms may also be present. A chlorine substituent is named "chloro," a fluorine substituent is named "fluoro," and a hydrogen substituent is named "hydro." Where more than one atom of a particular substituent is present, the prefixes shown in Table 1 are used.

In the IUPAC naming system as used for halocarbon refrigerants, each substituent has a number indicating its position on the molecule, unless no ambiguity is caused by omitting the number. For example, fluoroethane (CH_3CH_2F) does not require numbering, but 1,2-fluoroethane (FCH_2CH_2F) does, to distinguish it from 1,1-difluoroethane (F_2CHCH_3).

Table 1. Prefixes.

Number of Atoms of Substituent	Prefix
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca
11	undeca
12	dodeca

The carbon chain of the molecule is numbered to give the lowest sum of numbers to the substituents. For example, the molecule $CH_2ClCHClCHCl_2$ is named 1,1,2,3-tetrachloropropane (numbered from the right), not 1,2,3,3-tetrachloropropane (numbered from the left). If the sum of the substituent numbers would be the same from either end, the first group alphabetically takes priority. For example, CH_2FCH_2Cl is named 1-chloro-2-fluoroethane (not 2-chloro-1-fluoroethane).

Prefixes such as di-, tri-, tetra-, etc. are ignored in the alphabetization of substituents. These prefixes are inserted after the substituent names, such as "chloro" and "fluoro," have been alphabetized. Therefore, "chloro" always comes before "fluoro," no matter how many of each are present. For example, the compound CHF_2CFCl_2 is named 1,1-dichloro-1,2,2-trifluoroethane rather than 1,2,2-trifluoro-1,1-dichloroethane.

The prefix "per" indicates that every possible site on the carbon skeleton is occupied by the same type of substituent. For example, perfluoropropane is $CF_3CF_2CF_3$.

Halocarbon Numbering System

The general practice in the refrigeration industry is to designate various halocarbons with a number. The "Halocarbon Numbering System" (sometimes called the CFC, Freon, or Refrigerant Numbering System) is widely used in both national and international regulations. It was developed by DuPont for Freon chemicals in the late 1930s, and was later expanded and formalized into a standard by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the American National Standards Institute (ANSI) (Number Designation, 1989).

In past decades, many refrigerant chemicals were given numbers preceded by the designation "Freon," but since Freon is a trade name, other prefixes are now used. In the refrigeration industry, the halocarbon number has usually been preceded with an

"R."* More recently, a series of letters denoting the type of compound is often used. For example, compounds containing only chlorine and fluorine (in addition to carbon) have numbers preceded by "CFC." Though not standardized, other prefixes are increasingly used.

Table 2 lists the prefixes in general use, excluding prefixes for iodine-containing compounds. Note that two prefixes are used for perfluorocarbons: "FC" and "PFC." Note also that the Halocarbon Numbering System is beginning to be used for ethers (compounds that contain a C-O-C group, where "O" is oxygen). Thus, "HFE" denotes a hydrofluoroether.

In the Halocarbon Numbering System, the first number gives the number of carbon atoms minus one, the second gives the number of hydrogen atoms plus one, and the third gives the number of fluorine atoms. All remaining atoms are assumed to be chlorine atoms. An initial zero (indicating a one-carbon compound) is omitted. The total number of atoms attached to carbons on the carbon chain for most applicable compounds is 2n + 2, where "n" is the number of carbon atoms. Thus, methanes have four attached atoms, ethanes have six atoms, and propanes have eight atoms. As an example of this designation system, CFC-12 has one carbon (initial zero dropped), no

Table 2. Prefixes for halocarbon numbers.

Prefix	Elements in Chemical	Chemical Family
BC	Br, C	Bromocarbon
BCC	Br, Cl, C	Bromochlorocarbon
BCFC	Br, Cl, F, C	Bromochlorofluorocarbon
BFC	Br, F, C	Bromofluorocarbon
CC	Cl, C	Chlorocarbon
CFC	Cl, F, C	Chlorofluorocarbon
FC	F, C	(Per)fluorocarbon
FE	F, C, O	(Per)fluoroether
HBC	H, Br, C	Hydrobromocarbon
HBCC	H, Br, Cl, C	Hydrobromochlorocarbon
HBCFC	H, Br, Cl, F, C	Hydrobromochlorofluorocarbon
HBFC	H, Br, F, C	Hydrobromofluorocarbon
HC	H, C	Hydrocarbon
HCC	H, Cl, C	Hydrochlorocarbon
HCFC	H, Cl, F, C	Hydrochlorofluorocarbon
HFC	H, F, C	Hydrofluorocarbon
HFE	H, F, C, O	Hydrofluoroether
PFC	F, C	Perfluorocarbon
PFE	F, C, O	Perfluoroether

*In this report, the "R" prefix is used only for refrigerants that are mixtures (blends) of two or more chemicals.

hydrogen atoms (0 + 1 = 1), two fluorine atoms and, by default, two chlorine atoms. Thus, the formula is CF_2Cl_2.

Note that several isomers may have identical halocarbon numbers. Isomers are compounds that have identical numbers of each type of atoms, but have those atoms connected in different ways. For example, CF_3CCl_3 and $CClF_2CCl_2F$ would both be CFC-113 using the rules described thus far. To distinguish isomers for ethane derivatives (such as the example just shown), a letter is added based on the symmetry of the molecule. For two-carbon compounds, the absence of a letter indicates the most symmetrical isomer, an "a" indicates the next most symmetrical isomer, "b" the next, and so on. The symmetry is determined by adding the atomic masses of the substituents on each carbon atom. The isomer with the smallest difference in the sum of the masses on the two carbon atoms receives no letter, the next smallest difference receives an "a", the next a "b", and so on. For example, isomers of dichlorodifluoroethane are as follows: HCFC-132 is CHClFCHClF, HCFC-132a is $CHCl_2CHF_2$, HCFC-132b is $CClF_2CH_2Cl$, and HCFC-132c is CCl_2FCH_2F.

For cyclic compounds, the prefix "C" precedes the halocarbon number. For example, perfluorocyclobutane (cyclo-C_4F_8) is C-318. Some would also write this as FC-C318, keeping the nomenclature for the chemical family. For ethenes (compounds that contain only two carbon atoms, which are attached by a double bond, and whose total number of substituents is six), a "1" is added as a fourth digit. Thus $CCl_2=CF_2$ is 1121a. The system can be extended to propenes (compounds that contain three carbon atoms, two of which are attached by a double bond); however, the designations become rather complicated.

For three-carbon compounds (propanes), the halocarbon numbering system is similar to that for two-carbon compounds; however, two letters are required to specify the isomer. The first letter refers to the central carbon atom of the propane. To assign this letter, one calculates the combined atomic mass of the substituents on this carbon atom. The letter "a" represents the largest mass possible, the letter "b," the next largest, and so forth. The letters for compounds containing Cl, F, and/or H are assigned as shown in Table 3.

The second letter specifying a propane isomer is determined by the difference in the combined atomic masses of the substituents on the two terminal carbon atoms. The smallest difference is assigned the letter "a," the next smallest difference is assigned the letter "b,"

Table 3. First suffix for propane halocarbon numbers.

Suffix	Chemical Group
a	$-CCl_2-$
b	-CClF-
c	$-CF_2-$
d	-CHCl-
e	-CHF-
f	$-CH_2-$

followed by "c," "d," and so forth. (This method differs from that for two-carbon compounds, in which the smallest difference has no letter.) For example, $CHCl_2CF_2CF_3$ (3,3-dichloro-1,1,1,2,2-pentafluoropropane) is designated HCFC-225ca, and the isomer $CHClFCF_2CClF_2$ (1,3-dichloro-1,1,2,2,3-pentafluoropropane) is HCFC-225cb.

Refrigerants

Table 4 lists seven halocarbon refrigerants with a significant history of use. Refrigerants with limited use, such as CFC-13 and R-503 (a mixture of 40 percent HFC-23 and 60 percent CFC-13) have been omitted. CFC-115 is not listed by itself because it is used only in mixtures. HCFC-123, HFC-134a, and some proprietary refrigerant replacements have started to be used commercially, but so recently that they have been included in the list of replacements rather than in Table 4.

Because they can deplete stratospheric ozone, many refrigerants now in common use are being phased out under both international and national regulatory actions. One measure of the relative abilities of substances to deplete stratospheric ozone is the ozone depletion potential (ODP). Arbitrarily, the ODP of CFC-11 is assigned as 1. If, on a per-pound basis, another chemical had only half the impact on the ozone layer that CFC-11 has, it would be assigned an ODP of 0.5. One with twice the impact would be given an ODP of 2. Table 4 gives the ODPs of the halocarbon refrigerants in use today.

CFC-11

CFC-11 is used extensively in centrifugal chillers for commercial air conditioning and for process water chilling.

Table 4. Halocarbon refrigerants in use, 1994.

Halocarbon Number	Chemical Formula	Chemical Name	ODP
CFC-11	CCl_3F	Trichlorofluoromethane	1.0
CFC-12	CCl_2F_2	Dichlorodifluoromethane	1.0
CFC-113	CCl_2FCClF_2	1,1,2-Trichloro-1,2,2-trifluoroethane	0.8
CFC-114	$CClF_2CClF_2$	1,2-Dichloro-1,1,2,2-tetrafluoroethane	1.0
R-500	CCl_2F_2 CH_3CHF_2	74% Dichlorodifluoromethane (CFC-12) 26% 1,1-Difluoroethane (HFC-152a)	1.0 0.0
R-502	$CClF_2CF_3$ $CHClF_2$	51% Chloropentafluoroethane (CFC-115) 49% Chlorodifluoromethane (HCFC-22)	0.6 0.05
HCFC-22	$CHClF_2$	Chlorodifluoromethane	0.05

CFC-12

CFC-12, the most widely used refrigerant, is a medium- and high-temperature refrigerant. Its largest use is in mobile air conditioning (MAC). It is also used in centrifugal and reciprocating chillers, retail food storage, cold storage warehouses, industrial process refrigeration, and small-volume applications such as home refrigerators and freezers, water coolers, and dehumidifiers.

CFC-113

CFC-113 was used in certain types of centrifugal chillers, but no equipment designed to use this refrigerant has been produced in recent years. Some CFC-113 is still being used to recharge old equipment.

CFC-114

CFC-114 is used primarily in U.S. Naval vessel centrifugal compressor systems.

R-500 and R-502

Two blended refrigerants are in general use: R-500 and R-502. These mixtures are "azeotropes." Azeotropic mixtures have compositions and boiling points that do not change as they evaporate. (Most mixtures are nonazeotropic, that is, their compositions change during evaporation. The most volatile component tends to evaporate first.)

R-500 is an azeotrope of about three-quarters CFC-12 (1.0 ODP) and one-quarter HFC-152a (zero ODP). R-500 is used primarily in centrifugal chillers.

R-502, used in medium- and low-temperature applications, is an azeotrope of about one-half CFC-115 (0.6 ODP) and one-half HCFC-22 (0.05 ODP). R-502 is primarily used in commercial low-temperature refrigeration (cold storage warehouses, industrial process refrigeration, retail food storage).

HCFC-22

HCFC-22 is the most widely used refrigerant for residential and commercial air conditioning and is also used in some retail food refrigeration. This high-pressure refrigerant is used with reciprocating, scroll, screw, and (to a lesser extent) centrifugal compressors. It is also used as a component of R-502.

Replacement Refrigerants

To replace the ozone-depleting refrigerants that are being phased out, a number of new refrigerants are now being developed. The pure halocarbon CFC replacements already being sold or near to commercialization are listed in Table 5. Here, the term "replacement" is used even though some of those listed are only proposed as replacements at present. Because HCFC-22 has long been used as a refrigerant, it is listed in Table 4. Note, however, that HCFC-22 is a proposed alternative in some applications for which CFCs are now used, so it could also be placed in Table 5.

Other replacement candidates, not listed in this table, are in earlier stages of research and development or are being considered for limited applications (such as cascade systems). Among those omitted, HFC-32, HFC-23, HFC-134, and HFC-143a could be fielded in the relatively near-term, and work is in progress on many far-term compounds such as fluoroethers and fluoropropanes. Here, the time to availability (near-term versus far-term) is determined primarily by requirements for toxicity testing. Far-term candidates have had little or no toxicity studies. Ammonia and other nonhalocarbon refrigerants that could serve as replacements are not listed here.

A large number of chemical blend, some of which are patented or proprietary, are now under development or are being commercialized as refrigerants. Some of these mixtures are binary (containing two chemicals), while others are ternary (containing three chemicals). Nonazeotropic refrigerant mixtures (NARMs) are also under evaluation. NARMs will probably be more difficult to recycle than azeotropes or pure chemicals since they change composition when they evaporate; however, in some cases they can greatly increase efficiency. Because of the large number of azeotropic and NARM blends under development, being commercialized, and being proposed, blends are not included in the table of replacement refrigerants.

Table 5. Selected pure replacement refrigerants.

Halocarbon Number	Chemical Formula	Chemical Name	ODP
HCFC-123	$CHCl_2CF_3$	2,2-Dichloro-1,1,1-trifluoroethane	0.02
HCFC-124	$CHClFCF_3$	2-Chloro-1,1,1,2-tetrafluoroethane	0.02
HCFC-142b	CH_3CClF_2	1-Chloro-1,1-difluoroethane	0.06
HFC-125	CHF_2CF_3	Pentafluoroethane	0.0
HFC-134a	CH_2FCF_3	1,1,1,2-Tetrafluoroethane	0.0
HFC-152a	CH_3CHF_2	1,1-Difluoroethane	0.0

Many of the replacement and proposed replacement chemicals are being evaluated for toxicity under the Program for Alternative Fluorocarbon Toxicity Testing (PAFT), a consortium of chemical manufacturers. In some cases, the toxicity evaluation is near completion. Candidate replacement refrigerants are also being evaluated for their environmental characteristics under the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS). Eventually, replacements must be approved by the U.S. Environmental Protection Agency (USEPA) under the Significant New Alternatives Policy (SNAP). The SNAP program is discussed further on page 28.

A summary of the most promising short-term replacements by use is shown in Table 6. Note that "near-term" must be emphasized here. A large number of other materials, in particular the blends, are longer term candidates and thus not listed. HCFC-22 is already widely used for some applications, in particular, stationary air conditioning. Thus, it is somewhat misleading to list this as a "candidate" for those applications. It is likely that HCFC-22 will be increasingly replaced by HFC-134a.

HCFC-123 is considered an alternative to CFC-11 in centrifugal chillers. The thermodynamic and thermal properties of these two refrigerants are almost identical. Although HCFC-123, a low-pressure refrigerant, is a highly efficient refrigerant, the energy penalty as measured by horsepower (HP) per ton in switching from CFC-11 to HCFC-123 runs from 3 to 8 percent. It has been claimed that with proper redesign, the energy penalty can be reduced to 2 percent. Traditional lubricants can be used with this refrigerant, but seals and gaskets will probably have to be changed.

There is one potential problem with HCFC-123. In toxicity testing under PAFT, some male rats developed benign tumors when exposed to low levels of HCFC-123 for long periods of time. Based on these results, DuPont reduced its recommended allowable exposure limit (AEL) from a time-weighted average (TWA) value of 100 parts per million (PPM) to 10 ppm for an 8- to 12-hour workday (this has since been increased to 30 ppm [HCFC, 1993]). Allied Signal has reduced its permissible exposure limit

Table 6. Near-term refrigerant replacements by use sector.

Use	Leading Candidate	Other Candidates
Domestic Refrigeration	HFC-134a	HFC-152a HCFC-22
Commercial and Industrial Refrigeration	HCFC-22	HFC-134a
Air Conditioners	HCFC-22	HFC-134a
Chillers	HCFC-123	HCFC-22 HFC-134a
Mobile	HFC-134a	

Source: Roke 1991.

(PEL) to 5 ppm for a 40-hour work week and to 10 ppm for an 8-hour period. Testing has indicated that for normal operations and servicing, levels to which workers are exposed are very low (0.6 ppm or less) for hermetic centrifugal chillers. Commercial chillers containing HCFC-123 are now available.

HCFC-124 is used in several blends with HFC-152a and HCFC-22. These ternary blends are proposed for replacement of CFC-12 and R-502 in chillers, refrigerators, and freezers. HCFC-124 is also being marketed in a nonblended form for use in centrifugal chillers and as a substitute for CFC-114.

HCFC-142b has been considered as an alternative for CFC-114. It is also a component in R-176, a blend of HCFC-142b, HCFC-22, and CFC-12 that has been considered for MAC applications, and it is being considered for use in a blend with HCFC-22.

HFC-125 is a proposed alternative for CFC-12 and CFC-502 in low-temperature systems. It is also being commercialized in a number of refrigerant blends.

HFC-134a has properties near those of CFC-12 and is a strong candidate as a CFC-12 substitute. It is also being examined as a replacement for R-502 in some applications. HFC-134a is not, however, considered a drop-in replacement. Although it is compatible with most gaskets and seals now used, it is incompatible with the paraffin- and naphthene-based lubricants used with CFC-12. Polyalkylene glycol (PAG) and ester-based lubricants appear to be suitable for use with this material.

HFC-134a is one of the least efficient of the candidate replacement refrigerants, although this appears to depend on the system and application. Equipment redesign will be needed to help compensate for efficiency loss. Some U.S. automobile manufacturers have introduced it in selected 1993 and later models. Several foreign car manufacturers have used HFC-134a for some time.

HFC-152a is being considered as a substitute for CFC-12 and R-502, either as the pure material or as part of the ternary blend of HFC-152a, HCFC-124, and HCFC-22 now under development. Three major advantages of HFC-152a are that it has a zero ODP, has a good energy efficiency, and is already commercially available. Two disadvantages are that lubricants other than those now used with CFC-12 will be required (a commercially available alkylbenzene appears to be best) and that this refrigerant is flammable. The flammability issue may prove a major barrier to many potential applications of this refrigerant.

The Montreal Protocol

The Montreal Protocol is an international treaty that limits production of ozone-depleting substances, including many refrigerants. The Protocol was prepared under the auspices of the United Nations Environment Programme (UNEP) and was signed in 1987 by the original group of participating nations. It was ratified by the United States in 1988 and entered into force 1 January 1989. The original unamended Montreal Protocol limited the consumption (defined as production minus exports plus imports) of CFC-11, -12, -113, -114, and -115, and of Halons 1211, 1301, and 2402, which are fire extinguishing agents. The Montreal Protocol has been amended twice: in London in 1990 and in Copenhagen in 1992. The amendments limit additional substances and increase the restrictions on consumption. The most recent restrictions are presented in Table 7.

A number of important facts about the Montreal Protocol follow:

- As it now stands, the Montreal Protocol restricts consumption (essentially, production) of ozone-depleting substances but does not restrict their use.
- The Protocol will allow production of chemicals for "essential" uses, to be determined at future meetings of the Parties to the Protocol. It is likely, however, that very few refrigerant applications will be among these.
- Deadlines are postponed for ten years for certain developing countries (termed "article 5 countries").
- Because the HCFC base (see Table 7) is ODP-weighted, each government must decide how to allocate its HCFC consumption. For example, a country could choose to produce larger amounts of low-ODP substances such as HCFC-123, smaller amounts of high-ODP substances such as HCFC-22 or HCFC-141b, or some balance between the two.

Table 7. Consumption cuts under protocol as amended in 1992.

Year[a,b]	CFCs (%)	Halons (%)	Methyl Chloroform (%)	Carbon Tetrachloride (%)	Methyl Bromide	HCFCs (%)	HBFCs (%)
1994	75	100	50				
1995				85	Cap		
1996	100		100	100		Cap	100
2004						35	
2010						65	
2015						90	
2020						99.5	
2030						100	

[a]Base years: CFCs in original Protocol, 1986; CFCs in 1990 amendment, 1989; halons, 1986; methyl chloroform and carbon tetrachloride, 1989; methyl bromide, 1991. Base for HCFCs is 1989 ODP-weighted HCFC consumption plus 3.1 percent of 1989 ODP-weighted CFC consumption.
[b]Annual consumption amounts must meet the prescribed cuts by 1 January of year cited.

- Although the Montreal Protocol treats all HCFCs equally, it is likely that the U.S. will treat HCFCs differently depending on their ODP. It now appears that HCFC-141b, HCFC-142b, and HCFC-22, which have higher ODPs, will be phased out earlier in the U.S. than will be HCFC-123 and HCFC-124.

To summarize the Protocol, newly produced CFC refrigerants will not be available after the end of 1995 in the U.S. and other developed nations, and, for all practical purposes, newly produced HCFC refrigerants will not be available after the end of the year 2019. Only recovered and recycled materials will be available. At present, there are no restrictions on production of HFC refrigerants, but the U.S. will restrict emissions.

The U.S. Clean Air Act Amendments of 1990

The U.S. Clean Air Act was first passed in 1970 to protect the environment against emissions of harmful chemicals and was amended in 1977 and 1990. The Clean Air Act as amended in 1990 contains regulations that meet or exceed the requirements of the Montreal Protocol as amended in 1990, but not the Protocol as amended in 1992. Thus, additional restrictions will be forthcoming.

The Act as it now exists is divided into eleven chapters, called "Titles." Title VI, "Stratospheric Ozone and Global Climate Protection," regulates the production, use, venting, labeling, and handling of CFC and HCFC refrigerants and other ozone-depleting substances. It also allows replacements for these substances to be controlled, including replacements that do not damage ozone. Sections of Title VI that have portions concerning the refrigeration and air-conditioning industry are described below.

Section 602

Section 602 lists ozone-depleting substances to be regulated. This section places ozone-depleting substances into two classes. CFC refrigerants (and other CFCs) are in Class I, and the less ozone-depleting HCFC refrigerants are in Class II. The Class I listing is further broken down in Groups I through V. Table 8 lists the substances controlled by the Act according to Class and Group (*Clean Air Act Amendments*, 1990). It is anticipated that additional substances will be added to the Class I and II lists. HFC refrigerants do not damage stratospheric ozone and are not listed, but they are subject to eventual recovery and recycling regulations.

The ODPs of all the Class I and a few of the Class II substances are listed in the Clean Air Act. These values, which are consistent with those specified in the Montreal

Table 8. Clean Air Act substances.

CLASS I	
GROUP I	CFC -11, -12, -113, -114, -115
GROUP II	Halons 1211, 1301, 2402,
GROUP III	CFC-13, -111, -112, -211, -212, -213, -214, -215, -216, -217
GROUP IV	carbon tetrachloride
GROUP V	methyl chloroform
CLASS II	
HCFC -21, -22, -31, -121, -122, -123, -124, -131, -132, -133, -141, -142, -221, -222, -223, -224, -225, -226, -231, -232, -233, -234, -235, -241, -242, -243, -244, -251, -252, -253, -261, -262, -271	

Note: Isomers of these substances are included except for 1,1,2-trichloroethane (an isomer of methyl chloroform).

Protocol, are shown in Table 9. They are designated as "Regulatory ODPs" because other, presumably more accurate, values have since been obtained.

Sections 604 and 605

Sections 604 and 605 provide schedules for the phaseout of production and consumption of substances listed in Section 602. The proposed and final rules of the

Table 9. Regulatory ozone depletion potentials.

Substance	ODP
CFC-11	1.0
CFC-12	1.0
CFC-13	1.0
CFC-111	1.0
CFC-112	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
CFC-211	1.0
CFC-212	1.0
CFC-213	1.0
CFC-214	1.0
CFC-215	1.0
CFC-216	1.0
CFC-217	1.0
Halon 1211	3.0
Halon 1301	10.0
Halon 2402	6.0
carbon tetrachloride	1.1
methyl chloroform	0.1
HCFC-22	0.05
HCFC-123	0.02
HCFC-124	0.02
HCFC-141b	0.1
HCFC-142b	0.06

Source: *Refrigeration*, 1989.

USEPA for implementing Section 604 have been published in the *Federal Register* (30 September 1991, 30 December 1991, and 30 July 1992).

Production of ozone-depleting substances is phased out in steps. As the Act currently stands, Class I substances (CFCs) may not be produced after the year 1999. However, because the Montreal Protocol has moved up the phaseout date for CFCs to 1996, the Clean Air Act will have to be amended to meet the new phaseout date. Moreover, U.S. President Bush announced a phaseout date of 1995 for CFCs and other ozone-depleting chemicals.

Starting 1 January 2015, the Clean Air Act bans Class II substances (HCFCs) from use, with two exceptions. Class II refrigerants that have previously been used and have been recovered and recycled may be used in any application, and both new and recycled Class II substances may be used as refrigerants in stationary refrigerators and air conditioners manufactured prior to 1 January 2020. Note that the latter exclusion does not hold for mobile air conditioners. Production of Class II substances must cease by the year 2030.

Limitations on production of ozone-depleting substances under the Clean Air Act are shown in Table 10.

Section 608

Section 608 contains requirements for controlling emissions of regulated substances during use and disposal of stationary (HVACR) air-conditioning and refrigeration equipment. It also bans deliberate venting during service, leak testing, and disposal.

As it now stands, the U.S. Clean Air Act allows for stiff penalties for violations. Deliberate releases of ozone-depleting substances can be punished by fines of up to $25,000 per day, and prison terms are possible.

Section 609

Section 609 deals with air conditioners for motor vehicles (cars, trucks, farm equipment) but excludes hermetically sealed refrigeration systems used in refrigerated transport trucks. Section 609 requires standards for technician certification and for equipment used in servicing motor vehicle air conditioners, and it restricts the sale of small containers of CFCs. This section excludes "do-it-yourself" repair of mobile air conditioners. The USEPA has published the final rules for Section 609 (*Federal Register*, 14 July 1992).

Table 10. Controls under the Clean Air Act Amendments of 1990.

Ozone-Depleting Substance	Baseline Year	Production Controls	
		January	% of Baseline
Class I Substances			
Group I: CFC-11, -12, -113, -114, -115	1986	1991 1992 1993 1994 1995 1996 1997 1998 1999 2000	85 80 75 65 50 40 15 15 15 0
Group II: Halon 1211, 1301, 2402	1986		
Group III: CFC-13, -111, -112, -211, -212, -213, -214, -215, -216, -217	1989		
Group IV Carbon Tetrachloride	1989	1991 1992 1993 1994 1995 1996 1997 1998 1999 2000	100 90 80 70 15 15 15 15 15 0
Group V Methyl Chloroform	1989	1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002	100 100 90 85 70 50 50 50 50 20 20 0
Class II Substances			
HCFC-21, -22, -31, -121, -122, -123, -124, -131, -132, -133, -141, -142, -221, -222, -223, -224, -225, -226, -231, -232, -233, -234, -235, -241, -242, -243, -244, -251, -252, -253, -261, -262, -271	To be selected by 31 December 1999	2015 2030	100 0
Note: Isomers of the above substances are included except for 1,1,2-trichloroethane (an isomer of methyl chloroform).			

Section 611

Section 611 deals with container labels. Effective November 15, 1992, any container of a Class I (CFC) or Class II (HCFC) substance or of any product containing a Class I substance must have the following label to be accepted for interstate commerce: "Warning: Contains [insert name of substance], a substance which harms public health and environment by destroying ozone in the upper atmosphere." A similar label will eventually be required for all products containing a Class II substance.

Section 612

Section 612, the final section of the Clean Air Act of interest to the refrigeration and air-conditioning industry, requires the establishment of a program for evaluating safe alternatives to CFCs and HCFCs. Under this section, the USEPA must enact rules to make it illegal to replace any Class I or Class II refrigerant or other chemical with a substitute that adversely affects human health or the environment if a safer chemical is available. In addition, the USEPA must publish a list of unacceptable substitutes, and a list of acceptable alternatives for those substitutes.

Section 612 has resulted in the development of the USEPA SNAP Program. The plan for the SNAP program and an initial list of decisions on acceptable and unacceptable halon substitutes were promulgated on 18 March 1994 (59 FR 13044). Subsequent lists of decisions were published 26 August 1994 (59 FR 44240), 26 September 1994 (59 FR 49108), and 13 January 1995 (60 FR 3318). Substances that are prohibited, acceptable only under certain conditions or for certain uses, or removed from a list of prohibited or acceptable substitutes are subject to public comment.

Regulatory and Standards Issues for Refrigerant Detectors

USEPA HVACR Regulations

Overview. On 14 May 1993, the USEPA issued rules on venting, recovery/recycling, and related topics under Section 608 of the Clean Air Act (28 FR 28660). This regulation contains no leak test requirements, but it is anticipated that such requirements will be forthcoming. The USEPA does urge that technicians make every effort to repair leaks. The regulations have three purposes:

1. To require service practices that maximize CFC and HCFC recycling during servicing and disposal of refrigeration and air conditioning equipment.
2. To establish requirements for certifying reclaimers and certifying recovery and recycling equipment.
3. To establish requirements for the safe disposal of refrigerants in equipment that is normally disposed of without dismantling (such as home refrigerators and mobile air conditioners).

Prohibition on Venting. Effective 1 July 1992, deliberate venting of refrigerants containing CFCs and HCFCs was prohibited. Only three types of releases are allowed:

1. "De minimis" quantities released while making good faith attempts to recover, recycle, or safely dispose of refrigerants.
2. Releases during normal operation of equipment (not including maintenance, servicing, or disposal) due to leaking and mechanical purging.
3. Releases of mixtures of nitrogen and HCFC-22 used as holding charges or leak test gases.

Service Practice Requirements. During recovery of refrigerants, systems other than small appliances must be evacuated to at least the vacuum level specified by the USEPA (Table 11). The required level of vacuum depends on whether the recovery/recycling (R/R) equipment used is manufactured more than 6 months after the 14 May 1993 publication of the final rule or prior to that time. No vacuum level is specified for small appliance repair; however, recovery of 80 to 90 percent of the refrigerant is required. Recovered refrigerants can be used in the same or other systems without restriction, as long as there is no change in ownership of the refrigerant. If ownership is transferred, recovered refrigerants must first be reclaimed to ARI 700 level of purity with a chemical analysis.

Equipment Certification. The USEPA requires all recovery/recycling equipment manufactured more than 6 months after publication of the final rule to be tested and certified. At that time, equipment being used to prevent venting must meet the evacuation standards shown in Table 11.

Table 11. Evacuation requirements.

Refrigeration or Air Conditioning System	Charge, Pounds	Inches of Mercury Vacuum	
		R/R < 6 mo.[a]	R/R ≥ 6 mo.[b]
HCFC-22 system	Under 200	0	0
HCFC-22 system	200 or over	4	10
Other high-pressure (Includes CFC-12, R-500)	Under 200	4	10
Other high-pressure (Includes CFC-12, R-500)	200 or over	4	15
Very high-pressure (Includes CFC-13, R-503)		0	0
Low-pressure (Includes CFC-11, HCFC-123)		25	25

[a]Recovery/Recycling equipment manufactured or imported before 15 November 1993.
[b]Recovery/Recycling equipment manufactured or imported on or after 15 November 1993.

Technician, Contractor, and Reclaimer Certification. The USEPA requires that all persons maintaining, repairing, or disposing of air conditioning and refrigeration equipment be certified by an approved organization. Moreover, only certified persons may purchase Class I or Class II refrigerants (CFCs or HCFCs). Contractors and reclaimers must also be certified.

Safe Disposal Requirements. Refrigerant must be removed from any equipment disposed of. For equipment that is normally dismantled prior to disposal (such as retail food and warehouse refrigeration systems, chillers, and industrial process refrigeration equipment), the charge must be removed by acceptable recovery procedures at the time of dismantling. For equipment that is normally disposed of intact (such as MACs, household refrigerators, or room air conditioners), the final person in the disposal cycle (for example, the landfill owner or the scrap metal dealer) is ultimately responsible for ensuring that the refrigerant has been recovered.

Hazardous Waste Disposal. Recovered and reclaimed refrigerants are not considered hazardous. Used oils contaminated with CFCs are also not considered hazardous as long as (1) they are not mixed with other waste, (2) they have been subjected to CFC recycling or reclamation, and (3) they are not mixed with used oils from other sources.

SAE Standards

The Society of Automotive Engineers (SAE) is preparing two standards applying to leak detectors. Neither standard has been released; however, both are available in draft form. Standard J1628, *Refrigerant Leak Detectors—Procedures for Use,* is designed for use in servicing mobile air conditioners, but much of the information applies to other leak pinpointing applications as well.

SAE Standard J1627, *Refrigerant Leak Detectors—Rating Criteria*, is under preparation. Standard J1627 establishes levels of sensitivity for leak detection methods and equipment. Although it is being written for detectors used in servicing mobile air conditioning systems, it will likely be adopted for all refrigerant detectors used for pinpointing leaks. The standard defines a test apparatus and procedure for determining the sensitivity of detectors to pinpoint leaks. Leak detectors are placed in Classes 1, 2, or 3, going from the most sensitive to the least sensitive. SAE Standards can be ordered from:

SAE International
400 Commonwealth Drive
Warrendale, PA 15096-0001
Telephone: (412) 776-4970
Facsimile: (412) 776-0790

ASHRAE Standards

ASHRAE has issued Standard 15-1994, *Safety Code for Mechanical Refrigeration* (1994), which restricts the amounts and usage of refrigerants according to (1) their toxicity, (2) their flammability, (3) the probability of system leakage, and (4) the occupancy of the area into which they can leak. The standard classifies refrigerants into Groups A1 through A3 and B1 through B3.

Following this standard, area detectors are required when refrigerants are used in unlimited amounts (allowed for industrial areas only), and must be located where refrigerant vapor from a leak is likely to concentrate. For Group A1 refrigerants, detectors must alarm when the oxygen content falls below 19.5 percent; for refrigerants in Groups A2 and A3 they must alarm at or below concentration levels listed in the standard; and for refrigerants in Groups B1, B2, and B3 (except for ammonia) they must alarm at or below the Threshold Limit Value (TLV) for the refrigerant (1990-1992 Threshold Limit Values, 1990). The scope of this technical report does not include oxygen detectors.

Area detectors are also required for machinery rooms, to alarm and to actuate mechanical ventilation at or below an oxygen concentration of 19.5 percent for Group A1 refrigerants, or at or below a refrigerant concentration equal to its TLV level for any other refrigerant except ammonia.

ASHRAE Guideline 3-1990, *Reducing Emissions of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications* (1990), covers all refrigeration and air-conditioning equipment and systems that use CFC refrigerants. This document discusses leak minimization and detection during manufacture, installation, and service; however, no information is provided on methodologies or refrigerant detector technology. ASHRAE standards can be ordered from:

ASHRAE, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
Telephone: (404) 636-8400
Facsimile: (404) 321-5478

3 Refrigerant Detection Using Gas-Phase Electronic Sensors

This chapter discusses the focus of this report: electronic refrigerant detectors that determine the presence of one or more gaseous refrigerants in air, and the technology behind their operation. Nonelectronic refrigerant leak detection technologies and electronic leak detection methods that do not rely on sensing air-borne refrigerant gases or vapors are discussed in Chapter 4.

Refrigerant detectors have two primary applications: pinpointing leaks, and area monitoring. Detectors for pinpointing leaks, also termed "leak detectors" in this report, are usually portable and have a probe that can be moved about the refrigerant system and storage tanks to determine the location of refrigerant leaks. Detectors for area monitoring are often, but not always, permanently mounted and continuously monitor enclosed facilities for the presence of refrigerant gas above a set level. Area detectors are available for both single and multiple zones. Some multiple-zone detectors have sensors located in various areas to check refrigerant levels, and the detection signals are then fed back to a central station for processing. Other multiple-zone detectors have tubes that pull air back to the central station from different areas for periodic sampling.

A third application is called "emissions detection" in this report. A detector for this application is portable, and designed for non-continuous area monitoring. Such detectors are used primarily for checking workplaces and for field work; however, they may be used to a limited extent for pinpointing leaks.

Evaluation Criteria for Refrigerant Detectors

An excellent, though brief, overview of refrigerant detectors and evaluation and selection criteria has been presented in a widely-circulated publication (DuPont, undated). Much of the following discussion is taken verbatim from that publication (with some changes to maintain the terminology used in this report), with the permission of DuPont. Sensitivity, detection limit, and selectivity are discussed below. Other

important evaluation criteria are response time, range, and reliability. Depending on the application, alarm capabilities, size, weight, and cost may also be important.

Sensitivity

The sensitivity of any device is defined as the amount of input (material being measured) necessary to generate a certain change in output signal. For detection of leaking refrigerants, the material is the vapor concentration being measured and the output is the reading from a panel meter, a voltage output, or some other display device. Detectors with high sensitivity require very little material to generate a large change in output signal, while detectors with low sensitivity require larger amounts of material to change the output signal. For example, a detector with high sensitivity may be able to accurately discriminate between concentration levels of 1 ppm and 2 ppm of vapor, while a low sensitivity detector may only be able to discriminate in increments of 20 ppm or higher.

The sensitivity of a device is determined by a number of factors. The most important factors for refrigerant detection are the method of detection and the material being detected. For example, an ionization detector (such as one with negative corona discharge or heated diode sensors) may demonstrate high sensitivity for CFC-12, lower sensitivity for HCFC-123, and very low sensitivity for HFC-134a. Sensitivity differences of 100 to 1000 fold have been reported when comparing CFC-12 to HFC-134a detection with some ionization-based detectors. In this case, the variations in sensitivity would be due to the presence of less chlorine (which is easily ionized and detected) as you move from the CFC to HCFC to HFC class of compounds. An infrared-based area monitor, on the other hand, will show roughly the same sensitivity to all three compounds mentioned above.

Another sensitivity factor is motion. Most detectors used for pinpointing leaks require moving a probe to find the leak location. As the speed of the probe increases, sensitivity decreases. For very small leak rates, the probe must be moved slowly. Yokogawa Corporation recommends that probe speed be no greater than 2 in. per second.

A high sensitivity is not always desirable. With many sensors, as the sensitivity increases, so do the chances of detecting compounds of no interest; thus, the sensitivity should be no higher than that needed to meet safety and environmental requirements. Many detectors allow the operator to set the sensitivity level.

Detection Limit

Well-defined sensitivity values do not exist for refrigerant detectors. When speaking of how "sensitive" a detector is, often this is referring to the *detection limit*, which is usually defined as the minimum amount of material a unit can sense that gives a signal at least two times the background noise level. A sensitive device does not necessarily have a low detection limit (it could have a high background electronic noise level), even though the two measures of performance usually tend to coincide.

Detection limits for monitors are measured in two ways: in oz/yr for pinpointing applications and in ppm for area monitoring. Portable leak pinpointers typically have detection limits around 0.25 oz/yr, while area monitors have detection limits as low as 1 ppm, although a more typical value is 3 to 4 ppm for most compounds. Some manufacturers give leak detection limits in cm^3/sec or cm^3/min. Where this is done, for this report a second value in oz/yr has also been calculated assuming that CFC-12 is the gas leaked. For CFC-12, the conversion is 1 cm^3/min > 98 oz/yr at normal temperatures and pressures.

Because a given detector's sensitivity can vary greatly with different compounds, the detector must be matched to the intended application. For example, an ionization detector that claims a detection limit of 0.25 oz/yr for CFC-12 does not work very well for HFC-134a detection. On the other hand, an ionization detector made specifically for HFC-134a may be too sensitive for pinpointing CFC-12. Some manufacturers are now considering an option that allows the operator to choose various sensitivity settings on a single instrument, based on the application.

Selectivity

For detecting refrigerant, selectivity can be defined as the ability to detect only the refrigerant of interest without interference from other compounds that may be present in the area. Selectivity is not very important for leak pinpointers, because once you pinpoint the leak, the refrigerant's identity is known.

While selectivity requirements for area monitoring will vary with each specific installation, some general statements can still be made:

- Because area monitors work on a continuous basis, they are exposed to more potential interfering compounds and a wider range of concentrations than a leak pinpointer, which is usually used for only minutes at a time. Thus, selectivity is more important for area monitors than for leak pinpointers.

- Selectivity is a required feature of an area monitor if there are other compounds present with vastly different TLVs. For example, many equipment rooms with HCFC-123 chillers (AEL = 10 ppm) also have chillers with CFC-11 (TLV = 1,000 ppm). Without being able to distinguish between the two compounds, a non-selective detector will alarm when 10 ppm of either refrigerant is detected, which can lead to concern about excessive HCFC-123 exposure when in reality there may be no exposure to that compound and only inconsequential exposure to the CFC-11. This can also lead to frequent false alarms and eventual complacency toward alarms. Nevertheless, some operators prefer nonspecific detection so that they will be alerted when any refrigerant is detected. The identity of the refrigerant will be discovered once the leak is pinpointed.

Detector Technologies

Refrigerant detectors can be divided into three classes of selectivity: nonselective, halogen-selective, and compound-specific. Nonselective detectors can sense a wide variety of gases, including ones that are not refrigerants. Halogen-selective detectors sense only compounds containing halogen atoms (for refrigerants, primarily chlorine and fluorine). Compound-specific detectors can be set to detect just one or a few specified refrigerants. In general, the cost and complexity of detectors increase as the selectivity increases (McClure and Anderson 1990).

Sensor technologies available within each of the three selectivity categories are summarized in Table 12 and are discussed in the sections below.

Nonselective Sensors

Flame Ionization. Flame ionization detection is extensively used in gas chromatography in chemical analysis work; however, this survey was able to identify only one portable gas analyzer (manufactured by Sensidyne, Inc.) using this technology in isolation. The gas is pulled into a hydrogen flame, where the ionized gas is detected with an electrode. Most gases containing carbon will produce a signal. Flame

Table 12. Commercial refrigerant sensor technologies.

Nonselective	Halogen-Selective	Compound-Specific
Flame ionization Gas-membrane galvanic cell Negative corona discharge Solid state Thermal conductivity	Electron capture Heated diode	Gas chromatography Infrared Mass spectra-based

ionization is not a common detection method for refrigerant monitoring or refrigerant leak detection, and can be considered as yet unproven for this application.

Gas-Membrane Galvanic Cell. The gas-membrane galvanic cell sensor uses membrane electrolysis to detect selected gases and measure their concentrations. These sensors cannot directly detect halocarbon refrigerants; the refrigerant gas is first pyrolyzed with a hot filament to give off a gas (usually hydrogen chloride [HCE] or hydrogen fluoride [HF]) to which the sensor is responsive. The gaseous pyrolysis product passes through a membrane and is absorbed into a thin-film electrolyte on the surface of a working electrode, where it participates in an oxidation-reduction (redox) reaction. An equivalent redox reaction occurs at a counter electrode, resulting in a current that is proportional to the gas concentration. The current, i, is given by Equation 1.

$$i=(nFaDC)/\delta \qquad \text{[Eq 1]}$$

where n is the number of electrons per mole of gas, F is Faraday's constant, a is the area of the working electrode, D is the diffusion coefficient of the gas, C is the gas concentration, and δ is the thickness of the diffusion layer (Komiya and Kimura 1990).

Gas-membrane galvanic cell detectors based on HCl detection are relatively specific for compounds containing chlorine. Those based on HF detection, however, will experience interference by other acid gases such as sulfur dioxide and nitrogen dioxide (SO_2 and NO_2). As yet, this technology has not been widely applied to refrigerants. Only one company (ENMET Corporation) using a gas-membrane galvanic cell sensor in a refrigerant detector was identified.

Negative corona discharge. Negative corona discharge detectors, which are widely used for refrigerant leak detection, use electrical ionization to detect gases. This type of detector contains two electrodes enclosed in a housing (the tip) that is exposed to the atmosphere and that is surrounded by a case, the tip shell. The potential difference between the electrodes is typically 1500 to 2000 volts (V). The atmosphere in the tip shell is ionized, causing a current flow between the anode and cathode at the tip. When a gas enters the tip, the dielectric breakdown potential of the atmosphere changes, and the small current change is translated into a signal.

The negative corona discharge detector is sensitive to halogen-containing materials, but is considered nonselective because it will also detect other compounds. It is more highly sensitive to refrigerants containing chlorine than to refrigerants containing only fluorine halogen atoms. It has a very rapid response and is widely employed in detectors used to pinpoint leaks in both HVACR and MAC equipment.

Solid state. Solid state sensors are metal oxide devices whose resistance changes when they are exposed to a gas or vapor that adsorbs on their surface. Different "promoters" can be added to increase the detectors' sensitivity to gases of interest and decrease interference by other gases. Solid state sensors differ in heater requirements; the Adsistor sensors require no heaters. Changing the operating temperature can decrease or increase selectivity and sensitivity. Solid state sensors vary significantly in composition, design, performance, sensitivity, and selectivity, to the point that some manufacturers feel that they cannot be grouped under a single category.

The most common solid state sensors are metal oxide semiconductors (MOS) containing sintered tin dioxide. When such semiconductors are heated (usually to around 750 °F [395 °C]) in the absence of oxygen, electrons flow easily through the grain boundaries of the tin dioxide particles. When oxygen is present, however, the absorbed oxygen provides a potential barrier in the grain boundaries by trapping electrons. When contaminant gases are absorbed, they are oxidized by the absorbed oxygen, lowering the potential barrier and increasing the conductivity.

Though MOS sensors require very low power input to the solid state device, often less than 1 μA, many of the semiconductor devices must be heated to several hundred degrees to ensure reversibility (the ability to respond to changes in contaminant gas concentrations). This requires a current of 0.25 to 1 amp in many commercial solid state sensors. Sensor response to increasing gas and vapor concentrations can be relatively rapid; however, response to decreasing concentrations is slower, because desorption of a measured gas is slower than adsorption. Metal oxide detectors are low-cost compared to most other detectors, but they have only moderate sensitivity compared to infrared detectors and may be subject to interference by other compounds, including water vapor.

Solid state sensors typically last 5 years or more, and lifetimes of 10 or more years are possible for some sensors in some applications. The sensors require infrequent calibration, no more than once a year for area monitoring and possibly less. Because they respond to changing (particularly, decreasing) refrigerant concentrations more slowly than do some other sensors, solid state sensors are used more often for area monitoring than for leak pinpointing.

Thermal conductivity. In general, contaminant gases conduct heat to a differing extent than does air. Thus, the presence of contaminants in air can be determined from the thermal conductivity of the mixture. Thermal conductivity detectors (TCDs) are sensitive to a very broad range of compounds; however, their sensitivity is relatively low. A few companies manufacture TCDs for pinpointing leaks.

Halogen-Selective Sensors

Electron capture. Electron capture detectors (ECDs) use the same type of sensor found in many gas chromatographs. A radioactive source (Nickel-63) in the detector emits electrons (β particles), which are in turn collected and create a current flow. When an electron-capturing gas such as a halogenated compound enters the detector, it captures electrons, which are then no longer available for collection. The reduction in electrons reaching the collector decreases the current. The current change activates the detector. ECDs are halogen-selective, but not halogen-specific; any electron-capturing gas (for example, sulfur hexafluoride) will be detected. Because oxygen is a good electron-capturing gas, special techniques (such as an argon sweep) are required to keep oxygen from the sensor.

Electron capture sensors have relatively long lifetimes. Ion Track Instruments is the only company identified as using this type of sensor.

Heated diode. In heated diode sensors (also called "thermal ionization" or "positive ion discharge" sensors), alkali metal atoms react with halogen atoms from a thermally decomposed halogen-containing gas to form ions. The Yokogawa Corporation heated diode sensor consists of a platinum heating coil (the anode) and a platinum tube filled with an alkali metal compound (the cathode). A schematic is shown in Figure 1. A current heats the anode to around 800 °C, and several hundred volts of DC current is applied between the anode and cathode. Any halogen-containing gas introduced into the sensor is thermally cracked to release halogen atoms. At the same time, part of the alkali metal compound in the cathode tube decomposes to give off alkali metal atoms, which migrate to the surface of the emitter. The halogen atoms capture electrons from the alkali metal to give pairs of positive and negative ions, which travel under the high electric field. The positive alkali metal cations are captured by the cathode, and the negative halide anions are captured by the anode. The resulting current is a measure of the concentration of the halogen-containing gas. Heated diode sensors are more sensitive to refrigerants containing chlorine than to those containing only fluorine halogen atoms.

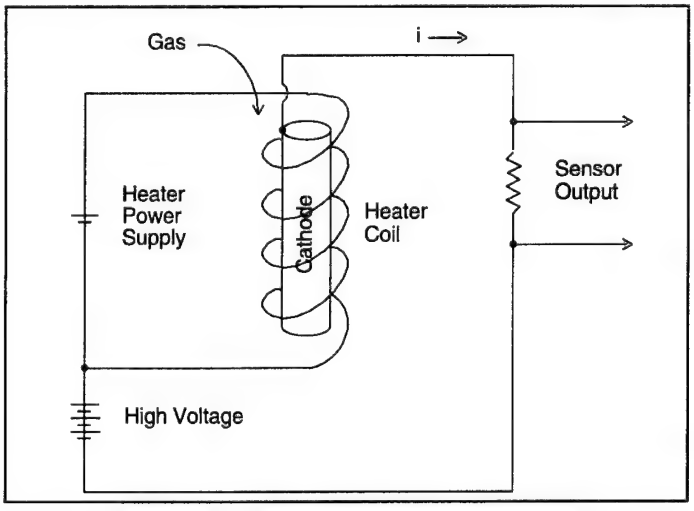

Figure 1. Schematic of Yokogawa heated diode sensor.

Leybold-Inficon detectors use a heated diode sensor containing a glass-ceramic element surrounded by a platinum heating wire. A schematic is shown in Figure 2 (U.S. Patent 1973).

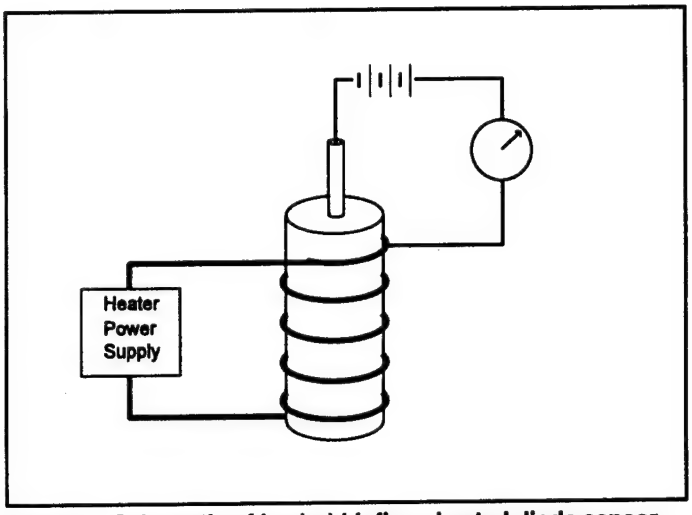

Figure 2. Schematic of Leybold-Inficon heated diode sensor.

The sensitivity of this type of sensor varies with the refrigerant to be detected (Table 13). In this table, the sensitivities have been related to that of CFC-12, which is arbitrarily given a value of 1. A larger number indicates a lower sensitivity. For example, CFC-13 with a sensitivity factor of 40 requires a concentration of 40 times that of CFC-12 to give the same response.

Table 13. Relative sensitivity of refrigerants for thermal ionization (heated diode) detectors.

Refrigerant	Sensitivity
CFC-12	1
CFC-11	0.75
CFC-13	40
HCFC-22	0.75
CFC-114	1.25

Source: *Leakage Testing Handbook*, 1969, Chapter 10.

Because of their high sensitivity and very rapid response, heated diode sensors are used more often for pinpointing leaks than for area monitoring. Among the disadvantages of using a heated diode detector is that high levels of ion flow will decrease its sensitivity. This could occur when the detector is exposed to a halogen-containing gas over an extended period. In addition, the high operating temperature of the detector can create a hazard in the presence of combustible gases. Heated diode sensors have to be replaced periodically.

Compound-Specific Sensors

Gas chromatography. Gas chromatography first separates gases in a mixture, then detects the individual components. The detection is usually performed with a thermal conductivity detector (TCD), flame ionization detector (FID), electron capture detector (ECD), or photoionization detector (PID). Gas chromatography can be used for area monitoring and (in theory) for leak detection. Automated sampling capabilities allow unattended monitoring with some instruments. Gas chromatography has been little used for refrigerant detection. Photovac is the only company identified as using this

technology for refrigerant monitoring; however, a large number of companies sell portable gas chromatographs, which could be used for this purpose.

Infrared. All refrigerants of interest to this report absorb infrared (IR) radiation, with each compound absorbing a different collection of frequencies. IR detectors pass a beam of IR radiation through a sensor and determine the absorption at selected wavelengths. Such instruments use a radiation source, a radiation detector, and a means (usually a pump) for passing refrigerant through the IR beam between the two. Three types of standard IR instruments are used: dispersive, nondispersive, and Fourier-transform, with the nondispersive being the most common. Dispersive instruments use a prism, grating, or interferometer to separate the incident IR beam into its spectral components. Nondispersive infrared (NDIR) detectors use filters to block all but a selected range of frequencies that are characteristic of the compound(s) to be detected. They typically use interference filters made of thin films of material laid down on a substrate in a vacuum chamber. By using a narrow band-pass filter, one can detect a specific refrigerant. Filters prepared with layers of two or three different materials pass a relatively narrow band with a specified wavelength. Typically, such filters have a band width of about 2 percent of the wavelength, although 1 and 5 percent filters are sometimes produced. Such narrow band pass filters can be produced for any specific wavelength in the IR and near-IR spectral regions. By using a broad band-pass filter, one can detect a range of refrigerants. One manufacturer (Eagle Creek Technology) refers to its IR detectors as "halogen-specific," though the term "halogen-selective" is preferred. Even the latter term is misleading, because IR detectors capable of detecting a range of refrigerants are not halogen-selective in the usual sense of the term, and IR detectors are usually considered to be compound-specific.

Fourier-transform infrared (FTIR) instruments use an interferometer to collect information over a range of wavelengths simultaneously. FTIR detection, which requires computer processing to convert the collected information to a "normal" IR spectrum, can rapidly collect multiple spectra. Sensitivities for all three types of instruments can be increased by increasing the pathlength through the air being monitored. Some instruments have variable pathlength capabilities.

The photoacoustic IR sensor represents a new technology. Samples of gas are exposed to pulsating IR radiation, which heats the gas and causes sound waves. The amplitude of the wave is proportional to the amount of absorbing gas present. A microphone detects the sound and provides an output signal.

Pyroelectric IR sensors are another new technology. Pyroelectric detectors use a thin wafer of lithium tantalate with electrodes deposited on both faces. When heated (for

example, by IR radiation), a charge develops between the two faces. Thus, these sensors can be used in IR-based analytical instruments. Since a charge is developed only when heat input is varied, the incoming IR beam must be chopped to effect a signal.

IR detectors are nearly always used for area monitoring rather than for pinpointing leaks, although Servomex makes one portable model that has been used for pin-pointing applications. IR detectors have a high sensitivity and can be designed to detect a single compound or several specific compounds without interference by other materials. However, IR detectors tend to be among the most expensive of the refrigerant detectors. Most IR detectors are configured as needed; few off-the-shelf units are available for refrigerants.

Mass spectra-based. Detectors based on mass spectrometry can be highly sensitive, and by programming to scan only certain mass peaks, only specified gases are detected. However, such detectors are the most expensive of all of the refrigerant detectors and require significant upkeep, high-vacuum systems as a component of the detector apparatus, and maintenance of acceptable ambient conditions. Only two companies, Balzers and Extrel, were identified as using this technology for refrigerant detection.

Assessment of Sensors and Detectors

Summary of Sensor Technologies

Table 14 summarizes some of the characteristics of the five most commonly found sensors in refrigerant detectors. Part of this information was taken from McClure, 1991, though some of the assessments differ from those in the cited reference. Note that sensors can vary widely depending on the design and the refrigerants to be detected. A sensor whose sensitivity is listed as "moderate" could be high in some cases and low in others. The fact that an extremely wide range of sensitivities have been reported, in particular for thermal conductivity detectors, points to a need for independent testing and certification.

In some cases, it is difficult to compare costs of different sensor technologies. For example, the negative corona discharge sensors are used only in detectors used to pinpoint leaks. Such detectors are relatively low-cost. On the other hand, solid state sensors are widely used for area monitoring, which has a much higher equipment cost.

Table 14. Summary of common detector types.

Sensor	Negative Corona Discharge	Solid State	Infrared	Heated Diode	Thermal Conductivity
Specificity	Nonselective	Nonselective	Compound-Specific	Halogen-Selective	Nonselective
Sensitivity	Moderate	Moderate (100 ppm or 0.25 oz/yr)	High (1 ppm or 0.0125 oz/yr)	High (5 ppm or 0.0005 oz/yr)	Low to High has been claimed
Maintenance/ Calibration	Low	Low	High	Low	Low
Cost	Low	Low	High	Low	Moderate
Most Common Usage	Pinpointing Leaks	Area Monitoring	Area Monitoring	Pinpointing Leaks	Pinpointing Leaks

The prices mentioned in the following discussion are summarized in Table 15. Prices are off-the-shelf, single-unit net retail prices or suggested prices without options, unless otherwise noted. GSA prices were not requested.

Detectors for Pinpointing Leaks

Selectivity is of little importance in detectors used to find leaks in refrigeration equipment. What is important is rapid response and high sensitivity. Handheld negative corona discharge detectors with audible, and sometimes visible, alarms have become the most widely used type of detector for pinpointing leaks. These detectors are extremely low-cost and are very reliable. Initial cost for the handheld negative corona discharge refrigerant leak detectors identified in this study runs from $89.99 to $355.69 depending on the options. The average price is $198. Different sensing probes or extender tips can add about $20.

Heated diode detectors have had moderate use as portable leak detectors. They have a very high sensitivity, in general higher than that of negative corona discharge or solid state detectors. This high sensitivity and their halogen selectivity increases their usefulness in refrigerant detection. However, heated diode detectors consume more power, which decreases battery life compared to negative corona discharge detectors (in many cases, the portables are line-powered). In addition, heated diode detectors, particularly line-powered ones, cost more than negative corona discharge detectors. Maintenance costs may be slightly higher as well. Only two battery-operated handheld heated diode leak detectors were identified, costing $375 and $399. Initial cost for line-powered heated diode leak detectors ranged from $385 to $4700, with an average price of $3,547.

Table 15. Detector prices found in this survey.

Sensor Technology	Price Range			
	Low, $	High, $	Average, $	Median, $
Pinpointing Leaks				
Negative Corona Discharge	90	356	198	195
Solid State (Battery Powered)	239	3,995	1,169	622
Solid State (Line Operated)	4,700 (One Only)			
Heated Diode (Battery Powered)	375	399	387	387
Heated Diode (Line Operated)	385	4,700	3,547	4,150
Thermal Conductivity	1,525	9,995	3,392	1,850
Mass Spectra-Based	31,370 (One Only)			
Electron Capture	10,955 (One Only)			
Area Monitoring				
Solid State (Single Channel)	110	2,345	937	1,492
Solid State (Multiple Channel)	1,050	9,910	3,685	2,785
Infrared (Single Channel)	2,000	35,000	8,919	5,725
Infrared (Multiple Channel)	1,250	48,722	*	*
Heated Diode (Single Channel)	5,170	5,832	5,591	5,170
Heat Diode (Multiple Channel)	9,700	14,200	11,700	11,200
Mass Spectra-Based	56,500	120,000	83,500	78,750
Gas-Membrane Galvanic Cell	5,200	5,400	5,300	5,300
Gas Chromatography	19,500 (One Only)			

* Because of the side variation in options and number of channels, the average and median values for multiple-channel IR detectors would have little significance.

Detectors with solid state sensors have also received only moderate use as portable leak detectors. While interferences can be made smaller with solid state sensors, detectors with these sensors have a slower response than either the negative corona discharge or heated diode detectors, and may therefore be better suited to area monitoring. Only one solid state detector used for pinpointing leaks was line-powered; it was priced at $4,700. The solid state, battery-powered detectors for pinpointing leaks ranged from $239 to $3,995 with an average price of $1,169 and a median price of $622.

Maintenance costs of detectors for pinpointing refrigerant leaks using negative corona discharge, heated diode, or solid state sensors are so small that they need not be considered. Occasional replacement of the sensor element and, in some cases, batteries is required; however, the annual cost for such items is likely to be under $100.

In some cases there may be a labor cost for calibration, but extensive calibration of leak detection equipment is usually not required. The negative corona discharge and heated diode detectors should have no difficulty in meeting any anticipated EPA requirements. It is uncertain whether some detectors with solid state sensors would have difficulty detecting small leaks because of their slower response. The large variations in solid state sensor technology, however, make it likely that many solid state detectors are quite suitable for pinpointing leaks. Eventually, detectors for pinpointing leaks may be certified under SAE Standard J1627 or other standards. Until such time as uniform testing by independent laboratories is available, it is difficult to distinguish the relative effectiveness of these three types of detectors.

Only for unusual applications is there any reason to select detectors having other sensor technologies (thermal conductivity, mass spectrometry, or electron capture) for pinpointing leaks. Thermal conductivity detectors are relatively expensive ($1,525 to $9,995 with an average price of $3,392 and a median price of $1,850), and mass spectra-based detectors are extremely expensive (the only mass spectra-based detector identified for pinpointing refrigerant leaks has a price of $31,370). There has been too little experience with electron capture leak detectors to allow adequate assessment of this technology. The only electron capture leak detector identified is priced at $10,955.

Detectors for Area Monitoring

Detectors to continuously monitor areas for the presence of refrigerants vary widely in capabilities. Small wall-mounted, single-channel detectors with solid state sensors and having only relay or analog outputs may cost less than many handheld leak detectors. On the other hand, programmable IR-based detectors capable of monitoring for many refrigerants in many areas may cost around $50,000. Two types of detectors that have received wide use in continuous monitoring are IR detectors, which are used where selectivity is important, and detectors with solid state sensors for areas where interference from other gases is not believed to be a problem.

IR detectors have extremely high sensitivity. Moreover, they can be programmed to select only certain gases and ignore others. The major drawbacks are the high cost of repair in the event of breakdown, and that periodic checks may be required to ensure that the detectors are operating properly. Single-channel IR detectors for area monitoring identified in this study vary in price from under $2,000 to $35,000, with large variations in options. The average price is just under $8,919. Prices of the multichannel instruments vary from $1,250 to $48,722 depending on the number of channels and other options.

Detectors with solid state sensors are a low-cost option for area monitoring when lower selectivity and sensitivity is not a problem. Such detectors are easier and cheaper to obtain for multiple-zone detection than infrared detectors. In fact, most of the solid state detectors sold for area monitoring have multizone capabilities. Price varies greatly depending on the alarm and programming options. Single-zone detectors range from $110 for a detector having only an analog output to $2,345 for a detector with alarm and relay capabilities. The average cost for single-zone solid state area monitors identified in this report is $937, with a median cost of $1,492. A number of single-zone instruments have prices below $500. Multiple-zone instruments surveyed here range from $1,050 to $9,910 with an average price of $3,685 and a median price of $2,785. As would be expected, the prices are highly dependent on the number of zones monitored.

Maintenance of detectors for area monitoring is considerably more costly than maintenance of detectors for pinpointing leaks. Sensor replacement is probably less important than the periodic calibration and operational checking that will be needed. Calibration is likely to be particularly important for refrigerant rooms containing HCFC-123, for which exposure level is limited under ASHRAE standards and will likely be limited under EPA requirements. (For facilities using HCFC-123, IR detectors may be required to eliminate the false alarms that tend to occur when detectors with solid-state sensors are set to low detection levels.) Costs for maintenance of very simple solid state detectors with single channels and few outputs may run less than $100 per year. On the other hand, material and labor costs for maintenance, periodic calibration, and system checking for programmable IR detectors having multiple channels and sensors could run over $1,000 per year.

Though heated diode detectors are much less common, their high sensitivity and moderate selectivity makes them attractive. However, only one company selling heated diode detectors for area monitoring (SenTech Corporation) was identified in this survey. These heated diode detectors are more expensive than solid state-based detectors ($5,170 to $14,200 depending on the number of zones), but this type of detector may be a good option when sensitivity and selectivity levels between those of the IR detectors and the solid state detectors are desirable.

Detectors using mass spectra-based, gas-membrane galvanic cells, and gas chromatography sensing technologies are available; however, these detectors are much less widely used than are the IR and solid state area detectors. Gas chromatographic and mass spectra-based detectors are expensive (the latter extremely so—up to $120,000).

Electronic Detector Use

Calibration

Detectors giving a readout of concentration or leakage rate require calibration. Some types of detectors are calibrated at the factory. Others are calibrated using internal standards. Still others require the use of external standards. Leak calibration standards are available from several sources.

Yokogawa Corporation of America sells a variety of standards for calibrating detectors used to pinpoint leaks. The standards allow the delivery of either CFC-12 or HFC-134a at given leak rates ranging from 17 x 10^{-5} oz/yr (3 x 10^{-8} cm^3/sec) to 17 oz/yr (3 x 10^{-3} cm^3/sec) for CFC-12. The LS-20 halogen leak standard contains a reservoir of liquid refrigerant, which is valved into a ballast tank as a gas. The amount of leakage depends on the ballast tank pressure, which can be adjusted over a given range. Calibrated Leak Devices and Leak Capsules are available to provide specific leak rates. A Leak Standard Calibration Kit is available to verify the accuracy of a leak standard.

Vacuum Technology manufactures standards based on those issued by the National Institute of Standards.

Pinpointing Leaks

When using electronic leak detectors to pinpoint leaks, the following procedures are required to ensure that all leaks are located:

1. Visually inspect the air conditioning or refrigeration system for damage, corrosion, or leaking lubricant. Patches of oil are often the first indication of leaking; however, oil may not always be present with new or small leaks, and oil may be present for other reasons. The leak detector probe should be used to inspect these suspect points, as well as to inspect couplings, fittings, and service ports.
2. Because leaks may change with vibration, temperature, and pressure variation, systems should be checked under a variety of conditions, both while operating and not operating (Guide to Basic and Advanced Refrigerant Gas Leak Detection, 1992).
3. Continue inspection even after a leak is detected, to ensure that other leaks are not present. The probe should be moved over all potential leak sources in a continuous path to ensure that no leaks are missed. Evaporator section leaks are

often difficult to detect because the coil is normally not easily accessible. Sensing at the evaporator drain outlet may allow detection of a coil leak.

4. The probe should not be moved at a rate greater than 2 in. per second at a distance not greater than 0.5 in. from potential sources. The SAE J1628 draft standard recommends that the detector be located no further than 0.25 in. from sources.
5. Apparent leaks should be confirmed by blowing air over the area to remove any trapped gases that may be present, then rechecking the location.
6. It may be necessary to remove dirt and grease from potential leak sources before checking them.

Survey of Commercial Gas-Phase Electronic Detectors

Approximately 300 potential companies were identified from trade shows and exhibitions and from advertisements, news items, and listings in the publications shown in Appendix A, and an initial contact letter (Appendix B) was mailed out. The companies contacted are listed in Appendix C.

The companies responding by the date of this report are shown in Table 16. In all cases, companies were asked to review portions of the draft report concerning their electronic detectors and the sensor technology used in those detectors.

Table 16 lists 60 companies* and 141 detectors or groups of closely related detectors. The breakdown by type is shown in Table 17. The most common sensor types used are the: (1) solid state, which are used primarily but not solely in area monitoring detectors, (2) negative corona discharge, which are used only in portable detectors for pinpointing leaks, and (3) infrared, which are used almost exclusively for area monitoring.

Sensor Manufacturers

Although no attempt was made to identify manufacturers who produced only sensors rather than complete refrigeration detectors, the following sensor producers were found during the review of commercially available detectors discussed in Table 16.

* Four Seasons, Big A TempControl, and Factory Air are counted as three separate companies for this count, even though they are listed together in the table.

Table 16. Commercial gas-phase electronic detectors.

Model	Sensor Technology	Type	Application
	A. W. Sperry Instruments Inc.		
LD-10A	Negative corona discharge	Nonselective	Pinpointing leaks
AIM USA			
LOGIC Gas Detectors	Solid state	Nonselective	Emissions Detection
	Acme Engineering Products Inc.		
VOC-3 (R123)	Infrared	Compound-specific	Area monitoring
	American Gas & Chemical Company, Ltd.		
FGT-202	Negative corona discharge	Nonselective	Pinpointing leaks
	ATD Tools		
ATD-31090	Negative corona discharge	Nonselective	Pinpointing leaks
	Bacharach Inc.		
LEAKATOR 10	Solid state	Nonselective	Pinpointing leaks
	Balzers, High Vacuum Products		
FrigoSniff	Mass spectra-based	Compound-specific	Pinpointing leaks
Auto Cube	Mass spectra-based	Compound-specific	Area monitoring
	Brüel & Kjaer Instruments, Inc.		
1301	Infrared	Compound-specific	Area monitoring
1302	Infrared	Compound-specific	Area monitoring
	CCI Controls		
4040	Solid state	Nonselective	Pinpointing leaks
7708	Solid state	Nonselective	Pinpointing leaks
	CEA Instruments, Inc.		
ADC 7000 Series	Infrared	Compound-specific	Area monitoring
F-9200	Solid state	Nonselective	Area monitoring
F-9200P	Solid state	Nonselective	Emissions detection
F-9200 Multipoint	Solid state	Nonselective	Area monitoring
	Cosmos Gas Detection Products		
XP-316(S)	Solid state	Nonselective	Pinpointing leaks
XP-702S	Solid state	Nonselective	Pinpointing leaks
	CPS Products, Inc.		
L-780a Leak-Seeker	Negative corona discharge	Nonselective	Pinpointing leaks
L-790a Leak-Seeker	Negative corona discharge	Nonselective	Pinpointing leaks
RLM-1	Solid state	Nonselective	Area monitoring
RLM-2	Solid state	Nonselective	Area monitoring

Model	Sensor Technology	Type	Application
Danfoss Automatic Controls			
OzoneSaver LDS 2000 detector	Solid state	Nonselective	Area monitoring
Eagle Creek Technology			
HM-1	Infrared	Halogen-selective	Area monitoring
HM-2	Infrared	Halogen-selective	Area monitoring
HM-3	Infrared	Compound-specific	Area monitoring
HM-4	Infrared	Compound-specific	Area monitoring
Eco-Dyne			
AN134	Solid state	Nonselective	Pinpointing leaks
Encore Controls, Inc.			
OZZIE-1	Solid state	Nonselective	Area monitoring
OZZIE-3	Solid state	Nonselective	Area monitoring
OZZIE-8	Solid state	Nonselective	Area monitoring
ENMET Corporation			
ISA-44, ISA-44-2, ISA-44-OD, ISA-44E, ISA-44E-2	Solid state	Nonselective	Area monitoring
TG-4200, TG-4200 BA	Gas-membrane galvanic cell	Nonselective	Area monitoring
TG-4300, TG-4300 BA	Gas-membrane galvanic cell	Nonselective	Area monitoring
TG-4700, TG-4700 BA	Gas-membrane galvanic cell	Nonselective	Area monitoring
EPD Technology Corporation			
EPD-B4	Thermal conductivity	Nonselective	Pinpointing leaks
EPD-R1 GAS CHECK	Solid state	Nonselective	Pinpointing leaks
EPD-R2 GAS CHECK	Solid state	Nonselective	Pinpointing leaks
EPD-R3 Gas Alarm			Area monitoring
Everco Industries			
A9767	Negative corona discharge	Nonselective	Pinpointing leaks
A9771	Negative corona discharge	Nonselective	Pinpointing leaks
Extrel Mass Spectrometry			
Questor 2	Mass spectra-based	Compound-specific	Area monitoring
Questor 3	Mass spectra-based	Compound-specific	Area monitoring
Ford Motor Company, Rotunda Equipment Department			
161-00010	Negative corona discharge	Nonselective	Pinpointing leaks

Model	Sensor Technology	Type	Application
Four Seasons Manufacturing Company			
Big A TempControl			
Factory Air			
59486-134a	Negative corona discharge	Nonselective	Pinpointing leaks
59490 Leak Seeker	Negative corona discharge	Nonselective	Pinpointing leaks
The Foxboro Company			
Miran 1A	Infrared	Compound-specific	Area monitoring
Miran 1B2	Infrared	Compound-specific	Area monitoring
Miran 203	Infrared	Compound-specific	Area monitoring
Miran 981	Infrared	Compound-specific	Area monitoring
Miran 983	Infrared	Compound-specific	Area monitoring
Miran 984/101	Infrared	Compound-specific	Area monitoring
Gas Tech, Inc.			
RI-413	Infrared	Compound-specific	Emissions detection
1620	Infrared	Compound-specific	Area monitoring
Gem Products, Inc.			
TM207	Negative corona discharge	Nonselective	Pinpointing leaks
TM210	Negative corona discharge	Nonselective	Pinpointing leaks
General Analysis Corporation			
SAM-I	Infrared	Compound-specific	Area monitoring
Genesis International Inc.			
Sherlock 100	Solid state	Nonselective	Area monitoring
Sherlock 400	Solid state	Nonselective	Area monitoring
Sherlock Junior	Solid state	Nonselective	Area monitoring
Geopal System A/S			
GJ Series	Solid state	Nonselective	Emissions detection
GOW-MAC Instrument Company			
21-250	Thermal conductivity	Nonselective	Pinpointing leaks
Hitech Instruments			
HI 134a	Negative corona discharge	Nonselective	Pinpointing leaks
HI 300 TEL	Negative corona discharge	Nonselective	Pinpointing leaks
HI 400-A TEL	Negative corona discharge	Nonselective	Pinpointing leaks
Imperial Eastman			
Annie II A2-007			Pinpointing leaks
Annie II A2-007L			Pinpointing leaks
Annie II A2-007M			Pinpointing leaks
Annie II A2-007ML			Pinpointing leaks

Model	Sensor Technology	Type	Application
International Sensor Technology			
Wall-Mounted Models: AG2000, AG2002, AG2003, AG2004	Solid state	Nonselective	Area monitoring
Rack/Panel-Mounted Models: AG3100, AG3102, AG40, AG80	Solid state	Nonselective	Area monitoring
Portables: AG5000, AG5100	Solid state	Nonselective	Emissions detection
Remote Link System III	Solid state	Nonselective	Area monitoring
Ion Track Instruments Inc			
Leakfinder 134	Solid state	Nonselective	Pinpointing leaks
Leakmeter 120	Electron capture	Halogen-selective	Pinpointing leaks
Model 96 Leakseeker	Thermal conductivity	Nonselective	Pinpointing leaks
J and N Associates, Inc.			
Sensit HXG-1	Solid state	Nonselective	Pinpointing leaks
Sensit RFC	Negative corona discharge	Nonselective	Pinpointing leaks
Leybold-Inficon, Inc.			
D-Tek	Heated diode	Halogen-selective	Pinpointing leaks
HLD 3000	Heated diode	Halogen-selective	Pinpointing leaks
HLD4000, Series A	Heated diode	Halogen-selective	Pinpointing leaks
HLD4000, Series C	Heated diode	Halogen-selective	Pinpointing leaks
MAC Tools, Inc.			
AC134AJR	Negative corona discharge	Nonselective	Pinpointing leaks
AC134AP	Negative corona discharge	Nonselective	Pinpointing leaks
AC5550	Negative corona discharge	Nonselective	Pinpointing leaks
AC5650	Negative corona discharge	Nonselective	Pinpointing leaks
Macurco Inc.			
FD-11	Solid state	Nonselective	Area monitoring
FD-12	Solid state	Nonselective	Area monitoring
FD-21	Solid state	Nonselective	Area monitoring
FT-11	Solid state	Nonselective	Area monitoring
Matheson Safety Products			
8057	Thermal conductivity	Nonselective	Emissions detection
8065 Leak Hunter	Thermal conductivity	Nonselective	Pinpointing leaks
8067	Thermal conductivity	Nonselective	Pinpointing leaks
Custom Gas Detection Systems	Solid state	Nonselective	Area monitoring

Model	Sensor Technology	Type	Application
	Mine Safety Appliances Company		
Chillgard	Solid state	Nonselective	Area monitoring
Chillgard IR	Infrared	Compound-specific	Area monitoring
Lira 202	Infrared	Compound-specific	Area monitoring
Lira 3000	Infrared	Compound-specific	Area monitoring
Lira 3250	Infrared	Compound-specific	Area monitoring
	Motors & Armatures, Inc.		
MARS H-10G	Heated diode	Halogen-selective	Pinpointing leaks
	Murray Temperature Control		
209907	Negative corona discharge	Nonselective	Pinpointing leaks
209909	Negative corona discharge	Nonselective	Pinpointing leaks
	Pacer Industries, Inc.		
LD1	Negative corona discharge	Nonselective	Pinpointing leaks
LD5	Negative corona discharge	Nonselective	Pinpointing leaks
	PAMA Electronics Company Ltd.		
GHD 2070	Solid state	Nonselective	Area monitoring
GHD 2075	Solid state	Nonselective	Area monitoring
	Photovac International Incorporated		
10S PLUS	Gas chromatography	Compound-specific	Area monitoring
	Ritchie Engineering Company Inc.		
69300	Negative corona discharge	Nonselective	Pinpointing leaks
69320	Negative corona discharge	Nonselective	Pinpointing leaks
69425	Negative corona discharge	Nonselective	Pinpointing leaks
	Robinair Division, SPX Corporation		
14970B	Negative corona discharge	Nonselective	Pinpointing leaks
W13480	Negative corona discharge	Nonselective	Pinpointing leaks
	Sensidyne, Inc.		
7012111-1	Flame ionization	Nonselective	Emissions Detection
	SenTech Corporation		
System 1000, Model 1020	Heated diode	Halogen-selective	Area monitoring
System 1000, Model 1030	Heated diode	Halogen-selective	Area monitoring
System 1000, Model 1033	Heated diode	Halogen-selective	Area monitoring
System 1000, Model 1300	Heated diode	Halogen-selective	Area monitoring

Model	Sensor Technology	Type	Application
System 2000, Model 2004	Heated diode	Halogen-selective	Area monitoring
Servomex Company			
Stationary Models	Infrared	Compound-specific	Area monitoring
PA404	Infrared	Compound-specific	Emissions detection
Siemens Industrial Automation, Inc.			
ULTRAMAT 5	Infrared	Compound-specific	Area monitoring
ULTRAMAT 21	Infrared	Compound-specific	Area monitoring
ULTRAMAT 22	Infrared	Compound-specific	Area monitoring
Snap-On Tools Corporation			
ACT5550	Negative corona discharge	Nonselective	Pinpointing leaks
ACT5555	Negative corona discharge	Nonselective	Pinpointing leaks
ACT5575	Negative corona discharge	Nonselective	Pinpointing leaks
Technical Chemical Company			
Sercon Leak Detector (8336)	Negative corona discharge	Nonselective	Pinpointing leaks
The Trane Corporation			
Refrigerant Monitor	Infrared	Compound-specific	Area monitoring
Thermal Gas Systems, Inc.			
Haloguard	Solid state	Nonselective	Area monitoring
Haloguard 10	Solid state	Nonselective	Area monitoring
Haloguard II	Solid state	Nonselective	Area monitoring
Haloguard II with IRGA Accessory	Infrared	Compound-specific	Area monitoring
TIF Instruments, Inc.			
TIF H10A	Negative corona discharge	Nonselective	Pinpointing leaks
TIF 5050	Negative corona discharge	Nonselective	Pinpointing leaks
TIF 5550	Negative corona discharge	Nonselective	Pinpointing leaks
TIF 5650	Negative corona discharge	Nonselective	Pinpointing leaks
Universal Enterprises, Inc.			
RLD1	Negative corona discharge	Nonselective	Pinpointing leaks
Vulcain Alarme Inc.			
Polygas VA-201	Solid state	Nonselective	Area monitoring
Yokogawa Corporation of America			
H10G	Heated diode	Halogen-selective	Pinpointing leaks
H10N	Heated diode	Halogen-selective	Pinpointing leaks
H25C	Heated diode	Halogen-selective	Pinpointing leaks

Table 17. Number of detectors by application and type.

Sensor Technology	Application			Total
	Pinpointing Leaks	Area Monitoring	Emissions Detection	
Solid State	10	27	4	41
Negative Corona Discharge	38	0	0	38
Infrared	0	26	2	28
Heated Diode	8	5	0	13
Thermal Conductivity	5	0	1	6
Mass Spectra-Based	1	3	0	4
Gas-Membrane Galvanic Cell	0	3	0	3
Flame Ionization	0	0	1	1
Gas Chromatography	0	1	0	1
Electron Capture	1	0	0	1
Unknown	5	1	0	5
Total	67	66	8	141

Adsistor Technology

Adsistor Technology manufactures a vapor sensor for use in equipment for detection of refrigerants and other gases and vapors. The company does not manufacture complete refrigerant detection systems. The sensor is an adsorption-sensitive solid state resistor whose resistance increases upon exposure to vapor. Unlike most solid state resistors, however, this one requires no heater. For most gases at a constant temperature, the resistance R changes with the concentration C of the gas or vapor being measured according to the relationship in Equation (2). In this equation, R_b is the resistance in the absence of the vapor or gas being detected and K is a constant that depends on the gas being measured and the temperature.

$$R = R_b 10^{C/K} \qquad \text{[Eq 2]}$$

The Adsistor sensor is nonselective and detects a number of compounds. It is virtually unaffected by water vapor. Its sensitivity is highest for gasoline and lowest for CFC-12 and water vapor (Table 18). The sensitivity decreases with increasing temperature.

Table 18. Adsistor sensitivity.

Gasoline	highest
Methyl Ethyl Ketone	
Amyl Acetate	
Halothane Anesthetic	
Trichloroethane	
Isopropyl Alcohol	
Ethylene Oxide	
CFC-12	
Water Vapor	lowest

Eltec Instruments, Inc.

Eltec manufactures a large number of different types of IR pyroelectric sensors. Some Eltec customers are using these in refrigerant detectors that are now commercially available.

Figaro USA, Inc.

Figaro manufactures three solid state sensors (TGS-830, TGS-831, and TGS-832) that are fairly widely used in refrigerant detectors. The company has developed a large amount of data relating sensor response and gas concentrations for CFC, HCFC, and HFC refrigerants.

4 Refrigerant Detection Using Other Technologies

This chapter discusses detection methods that do not rely on using electronics to detect refrigerants in the atmosphere outside of the refrigeration or air conditioning system.

Technologies

Bubble-Forming Solutions

Bubble-forming solutions are sprayed onto joints and other points in a system where leaks could occur. The formation of bubbles indicates a leaking refrigerant. Some products are fluorescent; however, it has been reported that fluorescent dye significantly decreases a solution's leak reaction sensitivity (Pastorello, 1991). Oils and greases, found on many refrigeration systems, are antifoamers and can also decrease bubble formation. Because drainage and drying decrease the leak detecting ability of bubble-forming solutions, some contain additives to increase viscosity, decreasing evaporation and allowing them to cling to a surface.

In most cases, bubble solutions are unable to detect leaks below 10^{-4} cm^3/sec (about 10^{-1} oz/yr), although greater sensitivity has been reported for some solutions (Pastorello 1991). In spite of their low sensitivity, bubble-forming solutions provide a convenient and economical method for initial screening for large leaks prior to using an electronic leak detector. However, it has been reported that the sodium lauryl sulfate detergent found in most bubble-forming solutions can interfere with subsequent use of some electronic leak detectors to pinpoint leaks (Barnett 1993).

Copper Flame

In a copper flame detector, the refrigerant is pulled into a gas (usually propane) flame where copper metal is present. The presence of halogen causes a green coloration. This technique must be used in a well-ventilated area and gives no indication of the magnitude of the refrigerant leak.

Detector Tubes

Detector tubes contain reagents that cause color changes when gases to be detected are pulled through the tube with a hand- or battery-operated pump. The ends of the sealed glass tubes are broken off immediately prior to use. The tubes are graduated, and the position where the color change occurs indicates the gas concentration. Because halogenated refrigerant gases are relatively inert and do not react directly with reagents to give color changes, the compounds must be pyrolyzed and the emitted hydrogen halide gas detected. At present, calibrated detector tubes are available only for refrigerants containing chlorine. Other materials containing chlorine must not be present, because they might also pyrolyze to emit hydrogen chloride, giving false CFC indications.

Fluorescence

Fluorescent leak detectors are chemicals that fluoresce under ultraviolet (UV) light. When these chemicals are dissolved in a system's refrigerant, points of leakage can be detected by irradiating the system with UV light. It is important that fluorescent chemical additives be compatible with the refrigerant and lubricating oils in the system and have an acceptable stability. ANSI/ASHRAE Standard 97-1983 (*Sealed Glass Tube Method*, 1989) is often used as a standard for testing stability. It has been reported that used refrigerants containing dyes are very difficult to reclaim, and such materials may be accepted by reclaimers only at a lower credit (Swain 1992). Moreover, it is expected that the SAE J1627 standard for leak detectors will require endorsement of dyes by manufacturers of air conditioners in which they are used.

In-System Vapor Detection

In-system vapor detectors determine the presence of vapor, which indicates liquid loss. Two types are in use. One employs a beam of light to detect vapor. The other uses a liquid float that measures the level of (chilled) liquified vapor. These detectors do not give a warning until significant refrigerant loss has occurred, but they do protect equipment and processes from harm caused by undetected loss of refrigerant.

Ultrasonic

Ultrasonic leak detectors sense the sound due to leakage out of pressurized or into evacuated systems. They are most widely used to check refrigeration equipment following manufacture or following installation but prior to operation. Ultrasound leak detection requires nitrogen pressurization or use of a sound generator located within the equipment (many units are sold with sound generators for this purpose). Most

ultrasonic leak detectors are battery powered. Although ultrasonic leak detectors have been used to check for leaking refrigerants, their sensitivity is low. In fact, some manufacturers do not list checking for escaping refrigerant as an application. Spraying the area containing the leak with water increases sensitivity with some detectors (gas escaping through the water generates noise). Related leak detectors operate by sound amplification.

Partial Survey of Commercially Available Detectors Using "Other" Technologies

Table 19 presents a summary of some of the commercially available leak detectors that use technologies other than those described in Chapter 3. This list is admittedly incomplete because this report is primarily concerned with electronic leak detectors capable of detecting refrigerants in the vapor phase in the atmosphere when they escape the system.

Table 19. Commercially available "other" technologies.

Company	Model	Type	Application
Advanced Research Technologies, Inc.	ART-711	Fluorescent additive for HFC refrigerants	Pinpointing leaks
Amprobe Instrument	SoundSleuth ULD-100	Ultrasonic	Pinpointing leaks
Bright Solutions, Inc.	ART-709	Fluorescent additive for CFC, HCFC refrigerants	Pinpointing leaks
	ART-711	Fluorescent additive for HFC refrigerants	Pinpointing leaks
	BSL-10; BSL-20; BSL-80	Fluorescent lamps	Pinpointing leaks
EnviroSystems Corporation	Guardsman	In-sysem vapor detection	System leaks
EPD Technology Corporation	EPD-500S Ultrasonic Scanner	Ultrasonic	Pinpointing leaks
Goodway Tools	ULD-90	Ultrasonic	Pinpointing leaks
H. B. Fuller Co.	TP-1430	Fluorescence	Pinpointing leaks
Highside Chemicals Inc.	TRAX	Bubble-forming solution	Pinpointing leaks
Hoke Inc.	Leak Detector	Bubble-forming solution	Pinpointing leaks
LA-CO Industries Inc.	Visu-Glow	Fluorescent bubble-forming solution	Pinpointing leaks
	Sure-Chek	Fluorescent bubble-forming solution	Pinpointing leaks
National Draeger, Inc.	100/a	Detector tube	Pinpointing leaks; area monitoring
National Refrigeration Products	NLDC	Bubble-forming solution	Pinpointing leaks
	NLDF	Fluorescent additive	Pinpointing leaks

Company	Model	Type	Application
Refrigeration Technologies	Big Blu	Bubble-forming solution	Pinpointing leaks
	Big Blue Low Temp	Bubble-forming solution	Pinpointing leaks
Ridge Tool Company	RLD-1000	Fluorescence kit	Pinpointing leaks
	RLD-1100	Fluorescence kit	Pinpointing leaks
Ritchie Engineering Co. Inc.	Yellow Jacket Leak Scanner System II	Fluorescence	Pinpointing leaks
Robinair Division, SPX Corporation		Fluorescence	Pinpointing leaks
Sensidyne, Inc.	+51, +51H, +51L	Detector tube	Pinpointing leaks; area monitoring
Spectronics Corporation	HVLD-80	Fluorescent additive	Pinpointing leaks
	HVLD-100	Fluorescent additive	Pinpointing leaks
	Glo-Stick GS-1, GS-2, GS-3, and GS-101 series	Fluorescent additive capsules	Pinpointing leaks
Stewart-Hall Chemical Corp.	Teltale Plus	Bubble-forming solution	Pinpointing leaks
	Teltale Zero Freeze	Bubble-forming solution	Pinpointing leaks
Superior Signal Co.	AccuTrak VPX	Ultrasonic	Pinpointing leaks
	AccuTrak VPE	Ultrasonic	Pinpointing leaks
TIF Instruments, Inc	TIF6500/6501	Ultrasonic	Pinpointing leaks
UE Systems Inc.	Ultraprobe 2000	Ultrasonic	Pinpointing leaks
Uniweld Products, Inc.	PLD33, PLD33V, PCLD33	Copper flame	Pinpointing leaks
UVP, Inc.	Reveal A-670	Fluorescent additive	Pinpointing leaks
Wagner Products Corporation	PRO-2000 Leak Finder	Fluorescent bubble-forming solution	Pinpointing leaks
	Radiant Leak-Finder	Fluorescent bubble-forming solution	Pinpointing leaks
	Leak-Finder	Bubble-forming solution	Pinpointing leaks
	AudioTech Probe	Sound amplification	Pinpointing leaks
Watsco Components, Inc.	Search DL-1, DI-1A, DL-2	Bubble-forming solution	Pinpointing leaks
	Search DL-1F	Fluorescent bubble-forming solution	Pinpointing leaks
	RLM	In-system vapor detection	System leaks
White Industries	Fluoro-Lite	Fluorescent additive	Pinpointing leaks

5 Summary

Running the HVACR systems "as is" with strict refrigerant leakage control is a cost-effective option for meeting current Army policy on CFC refrigerants (policy documents are listed at the beginning of Chapter 1) and the U.S. Clean Air Act Amendments of 1990 (details in Chapter 2, *The U.S. Clean Air Act Amendments of 1990*). Early detection of refrigerant leakage is a critical step in containing refrigerants within the HVACR systems. An exhaustive survey of the detecting tools available in the commercial market as of 1993 has been presented in this report. Type, operating principle, and application usage of each detector have been categorized, and an estimate is given of the cost in the current market.

In this report, no attempt has been made to recommend specific detector types or manufacturers. This exhaustive report, however, will serve as a useful source of information on the availability of detectors matching an Army installation's need and application. USACERL is in the process of developing field testing and demonstration of a few typical detectors in each category, in cooperation with volunteering Army installations. If funded, the results from this field testing will be also reported in a USACERL technical report in the near future.

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Federal Register (FR), vol 56, No. 250 (30 December 1991), pp 67368-67373.

Federal Register (FR), vol 57, No. 147 (30 July 1992), pp 33754-33798.

Federal Register (FR), vol 57, No. 135 (14 July 1992), pp 31242-31265.

Federal Register (FR), vol 57, No. 11 (16 January 1992), pp 1984-1990.

Federal Register (FR), vol 58, No. 92 (14 May 1993), pp 28660-28734.

Federal Register (FR), vol 59, No. 53 (18 March 1994), pp 13044-13161.

Federal Register (FR), vol 59, No. 165 (26 August 1994), pp 44240-44256.

Federal Register (FR), vol 59, No. 185 (49108-49121), pp 49108-49121.

Federal Register (FR), vol 60, No. 9 (13 January 1995), pp 3318-3322.

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Leakage Testing Handbook, ch. 10 (National Aeronautics and Space Administration, 1969).

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McClure, D., and T. Anderson, "A Comparison of Refrigerant Constant Monitoring Leak Detectors," in David R. Tree, ed., *Proceedings of the 1990 USNC/IIR-Purdue Refrigeration Conference, 17-20 July 1990* (West Lafayette, IN), pp 308-312.

Number Designation and Safety Classification of Refrigerants, Standard 34-1989 (American National Standards Institute/American Society of Heating, Refrigerating, and Air Conditioning Engineers [ANSI/ASHRAE], 1989).

Pastorello, J., "Study of Leak Detection Fluids," *Materials Evaluation*, vol 49 (August 1991), pp 1035-1037.

"Protection of Stratospheric Ozone," *Federal Register*, vol 57 (10 December 1993), pp 58644-58692.

Reducing Emissions of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications, ASHRAE Guideline 3-1990 (ASHRAE, 1990).

Refrigeration, Air Conditioning and Heat Pumps Technical Options Report (United Nations Environment Programme, 30 July 1989).

Refrigeration Technologies (brochure), "Guide to Basic and Advanced Refrigerant Gas Leak Detection" (Fullerton CA, 1992).

Roke, L., "Refrigeration and Air-Conditioning," *UNEP Workshop on the Implementation of the Montreal Protocol for the Protection of the Ozone Layer* (Jomtien, Thailand, 26-29 November 1991).

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Sealed Glass Tube Method to Test the Chemical Stability of Material for Use Within Refrigerant Systems, ANSI/ASHRAE Standard 97-1983 (ASHRAE 1989).

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Swain, H., *Foraine Rollover Refrigerant Reclamation Program* (Elf Atochem North America, Inc., [Communication to Elf Atochem Foraine Wholesalers], 15 December 1992).

U.S. Patent 3,751,968 (14 August 1983).

List of Abbreviations

AC	alternating current
ACGIH	American Conference of Governmental and Industrial Hygienists
AEL	Allowable Exposure Limit
AFEAS	Alternative Fluorocarbon Environmental Acceptability Study
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BC	bromocarbon
BCC	bromochlorocarbon
BCFC	bromochlorofluorocarbon
BFC	bromofluorocarbon
C	carbon
CAA	Clean Air Act
CC	chlorocarbon
CFC	chlorofluorocarbon
CL	chlorine
cm	centimeter
CRT	cathode ray tube
db	decibel
DC	direct current
ECD	electron capture detector
F	fluorine
FC	(per) fluorocarbon
FE	(per) fluoroether
FID	flame ionization detector
FTIR	Fourier-transform infrafed
g	gram
GMGC	gas-membrane galvanic cell
H	hydrogen
HBC	hydrobromocarbon
HBCC	hydrobromochlorocarbon
HBCFC	hydrobromochlorofluorocarbon
HBCF	hydrobromofluorocarbon

HC	hydrocarbon
HCC	hydrochlorocarbon
HCFC	hydrochlorofluorcarbon
HFC	hydrofluorcarbon
HFE	hydrofluoroether
HP	horsepower
hr	hour
HVACR	heating, ventilation, air conditioning, and refrigeration
IR	infrared
IUPAC	International Union of Pure and Applied Chemistry
lb	pound
LCD	liquid crystal display
LED	light-emitting diode
mA	milliampere
MAC	mobile air conditioner
min	minute
MOS	metal oxide semiconductor
NARM	nonazeotropic refrigerant mixture
N/A	not applicable
NDIR	nondispersive infrared
NEMA	National Electrical Manufacturers Association
NiCad	nickel/cadmium
ODP	ozone depletion potential
oz	ounce
PAFT	Program for Alternative Fluorocarbon Toxicity Testing
PAG	polyalkylene glycol
PEL	permissible exposure limit
PFC	perfluorcarbon
PFE	perfluorether
PID	photoionization detector
POC	Point of Contact
ppb	parts per billion
ppm	part(s) per million
R/R	recovery/recycling
SAE	Society of Automotive Engineers
sec	second
SNAP	Significant New Alternatives Policy
TCD	thermal conductivity detector
TLV	Threshold Limit Value
TWA	Time-Weighted Average
UNEP	United National Environment Programme

UV	ultraviolet
USACERL	U.S. Army Construction Engineering Research Laboratories
USACPW	U.S. Army Center for Public Works
USEPA	U.S. Environmental Protection Agency
V	volts
VAC	volts, alternating current
VDC	volt, direct current
yr	year
μA	microampere

Appendix A: Publication Sources Used To Identify Companies

1992 HVACR Directory Issue
Business News Publishing Co.
P.O. Box 2600
Troy, MI 48007-9940

The Air Conditioning, Heating and Refrigeration News
Business News Publishing Co.
P.O. Box 2600
Troy, MI 48007-9940

Appliance Service News
110 West Saint Charles Road
P.O. Box 789
Lombard, IL 60148

ASHRAE Journal
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.,
1791 Tullie Circle NE
Atlanta, GA 30329

Automotive Cooling Journal
P.O. Box 97
East Greenville, PA 18041

Distributor Magazine
A Palmer Publication
651 W. Washington, Suite 300
Chicago, IL 60661-9828

Energy User News
P.O. Box 2165
Radnor, PA 19080-9231

Engineered Systems
Business News Publishing Company
P.O. Box 7016
Troy, MI 48007-9911

Environmental Protection
Stevens Publishing Corp.
225 N. New Road
Waco, TX 76710

Indoor Comfort News
606 N. Larchmont Blvd., Suite 4A
Los Angeles, CA 90004

Journal of the Air & Waste Management Association
Three Gateway Center, Four West
Pittsburgh, PA 15222

Ozone Depletion Network Online Today
119 South Fairfax Street
Alexandria, VA 22314

Pollution Equipment News
9900 Babcock Blvd.
Pittsburgh, PA 15237-9915

Refrigeration Service & Contracting
Business News Publishing Company
P.O. Box 7021
Troy, MI 48007-9916

Sensors
Helmers Publishing, Inc.
174 Concord Street
P.O. Box 874
Peterborough, NH 03458-0874

Service Reporter
651 W. Washington Street, Suite 300
Chicago, Illinois 60661-2180

Supplier to Buyer
Business News Publishing Company
P.O. Box 2600
Troy, MI 48007

Thomas Register, 1992
Thomas Publishing Company
One Penn Plaza
New York, NY 1001

Today's Air Conditioning
680 Devonshire Blvd.
P.O. Box 521247
Longwood, FL 32752-1247

Appendix B: Electronic Detector Product Summary by Manufacturer

A.W. Sperry Instruments, Inc.

The LD-10A is a portable handheld leak detector that comes blister-packed complete with 9V alkaline battery, sensing tip, and a spare tip. An optional tip extension (approximately 8 in.) is available.

Table B1. A.W. Sperry Instruments, Inc.

Parameter	Model: LD-10A
Description	Handheld, portable, battery-powered leak detector
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC
Detection Limit	0.5 oz/yr
Response Time	"Instantaneous"
Detection Indicator	Light-emitting diode (LED) and variable frequency audible alarms
Power	9V alkaline battery
Battery Discharge Time, hr	10
Size (H x W x D, in.)	7 x 1.5 x 1.4
Weight, lb	0.375
Price	$99.95; EXT-1 Tip Extension: $19.95

AIM USA

AIM manufactures a large family of portable, handheld leak detectors having a range of available sensors with an emphasis on electrochemical and solid state (MOS) sensors. Only MOS sensors would be used for refrigerants. The detectors are primarily designed for emergency response, worker exposure, and other health/safety applications rather than for pinpointing leaks or continuous area monitoring. No detectors calibrated specifically for refrigerants are available as off-the-shelf units, but such detectors could be made available through special calibration of existing detectors.

Acme Engineering Products, Inc.

The Acme Engineering Products VOC-3 uses an IR-based detector for area monitoring for HCFC-123. The company can supply similar detectors calibrated for other refrigerants.

Table B2. Acme Engineering Products, Inc.

Parameter	Model: VOC-3 (R123)
Description	
Sensor Technology	Infrared
Application	Area monitoring
Refrigerants	HCFC-123; can be supplied for other refrigerants
Detection Limit	Two factory-calibrated operating levels
Response Time	<1 min
Detection Indicator	Audible alarm
Power	120 or 220 volts AC (VAC)
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	12 x 8 x 8
Weight, lb	15
Price	<$2,000

American Gas & Chemical Company, Ltd.

The FGT-202 is a handheld, battery-powered leak detector with a negative corona discharge sensor. Before use, the instrument is balanced with a balance knob to give a fast, steady ticking signal. When a refrigerant gas enters the sensing tip, the ticking speed increases to a low hum and then to a "siren" as the gas concentration increases. The detector has a light-emitting diode (LED) indicator showing when the power is on. The FGT-202 includes a carrying case, ear phones, spare sensing tip, and batteries.

Table B3. American Gas & Chemical Co., Ltd.

Parameter	Model: FGT-202
Description	Handheld, battery-powered leak detector
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	CFC-11, -12, -13, -113, -114; HCFC-22
Detection Limit	<0.5 oz/yr
Response Time	1 sec
Detection Indicator	Variable frequency audible alarm
Power	Four AA-cell alkaline batteries
Battery Discharge Time, hr	40
Size (H x W x D, in.)	7 x 3 x 1.75
Weight, lb	1.5 with batteries
Price	$209

ATD Tools

The ATD-31090 detector is manufactured for pinpointing leaks in the MAC market; however, it can be used for all halogen-containing refrigerants in other applications. The detector is sold only through an association of distributors.

Table B4. ATD Tools.

Parameter	Model: ATD-31090
Description	Handheld, portable, battery-powered leak detector
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr
Response Time	"Instantaneous"
Detection Indicator	LED and variable frequency audible alarms
Power	9V alkaline battery
Battery Discharge Time, hr	10
Size (H x W x D, in.)	7 x 1.5 x 1.4
Weight, lb	0.375
Price	$74.29

Bacharach, Inc.

The LEAKATOR 10 detector is for a variety of combustible and toxic gases, as well as refrigerants. The instrument includes an installed and calibrated gas sensor, flexible probe, carrying case, and earphone.

Table B5. Bacharach, Inc.

Parameter	Model: LEAKATOR 10
Description	Handheld detector with flexible 20-in. probe
Sensor Technology	Solid state
Application	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC
Detection Limit	50 ppm
Response Time	"Instantaneous"
Detection Indicator	Ten-LED display; visual and audible alarms
Power	Five C-cell batteries
Battery Discharge Time, hr	20
Size (H x W x D, in.)	8.5 x 2.25 x 1.75
Weight, lb	1.1
Price	$239

Balzers, High Vacuum Products

Balzers makes a variety of mass spectra-based gas detectors. The FrigoSniff is manufactured for pinpointing refrigerant leaks and the Auto Cube, one of several similar models, is appropriate for area monitoring for refrigerants.

Table B6. Balzers, High Vacuum Products.

Parameter	Model	
	FrigoSniff	Auto Cube
Description	Self-contained mass spectrometric detector with pump for pinpointing and quantifying refrigerant leaks with three gases selectable	Self-contained mass spectrometric detector with pump for area monitoring with 6 or 12 monitoring points, each programmable for up to 64 gases
Sensor Technology	Mass spectra-based	Mass spectra-based
Application	Pinpointing leaks	Area monitoring
Refrigerants	Selectable: HFC-134a; CFC-12; any other CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	HFC-134a: 0.01 oz/yr with 3-meter probe line; 0.03 oz/yr with 8-meter line	<1 ppm
Response Time	<1 sec	Number of seconds depends on sample line length
Detection Indicator	Analog meter in g/yr; 80-decibel (db) audible alarm; instrument-ready and leak alarm relays; remote display unit	Software (included) runs on personal computer (PC); displays and records data in several formats
Power	100/110 or 230 VAC	100/110 or 230 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	14.2 x 20.9 x 20.9	14.2 x 20.9 x 20.9
Weight, lb	66	75
Price	$31,370	$56,500/$62,500

Brüel & Kjaer Instruments, Inc.

The Model 1301 spectrometer is a transportable system; the Model 1302 is a totally portable system. Both use photoacoustic absorption. The Model 1301, which is an FTIR instrument, can be used for unattended, repetitive monitoring for concentrations of up to seven gases simultaneously. The Model 1302, a totally portable instrument, can be used for monitoring up to five gases. Both instruments require calibration at intervals of no less than 3 months.

Table B7. Brüel & Kjaer Instruments, Inc.

Parameter	Model	
	1301	1302
Description	Transportable FTIR photoacoustic instrument with internal memory storage and disk drive for data acquisition and storage allowing for monitoring of up to 7 gases	Portable NDIR photoacoustic instrument with nonvolatile internal memory storage for monitoring of up to 5 gases
Sensor Technology	Infrared	Infrared
Application	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	0.1 to 10 ppm (typical)	0.1 to 10 ppm (typical)
Response Time	75 sec for 1-meter sampling tube	~30 sec for 1 gas; ~105 sec for 5 gases
Detection Indicator	CRT display, alarm relays, RS-232 and IEEE-488 interfaces	Digital display, RS-232 and IEEE-488 interfaces
Power	90-140 or 180-264 VAC	90-140 or 180-264 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	8.1 x 16.9 x 19.7	6.9 x 15.6 x 11.8
Weight, lb	39.6	19.8
Price	$35,000	$20,000

CCI Controls

The Models 7708 and 4040 differ primarily in alarm. The 4040 has an audible alarm only; the 7708 has both an audible alarm and a meter.

Table B8. CCI Controls.

Parameter	Model	
	4040	7708.2
Description	Handheld portable with audible signal	Handheld portable with 1-in. diameter by 1.18-in. long probe attached by cord to unit; charger included with carrying case
Sensor Technology	Solid state	Solid state
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	CFC-11; HCFC-22; R-502	CFC-11; HCFC-22; R-502
Detection Limit	100 ppm	25 ppm for hydrocarbons
Response Time	0.5 sec	0.5 sec
Detection Indicator	Audible signal	Analog meter; audible signal each time gas level increases
Power	Four AA batteries plus 9V battery (included)	Eight nickel/cadmium (NiCad) AA-cell batteries; low-battery indicator
Battery Discharge Time, hr	AA batteries: 1 hr; 9V battery: 2 years.	3.5
Size (H x W x D, in.)	6.125 x 3.562 x 1.312	6.25 x 3.75 x 2.5
Weight, lb	0.6875	1.5 with batteries
Price	$285	$495

CEA Instruments, Inc.

The ADC 7000 IR-based detector is manufactured by Analytical Development Company (ADC) in England and is marketed by CEA. The IR detector has single-analysis optics calibrated for a specific gas, microprocessor control system, backlit graphic display, operator keyboard, and flowmeter with throttle. CEA manufactures a number of portable and fixed solid state Series U gas detectors; the F9200 models are for halocarbon refrigerants.

Table B9. CEA Instruments, Inc. IR-based detector.

Parameter	Model: ADC 7000 Series
Description	Nondispersive IR analyzer with 2 liter/min sample pump, available in three versions: double beam (DB00), rotating filter (RF00), and single beam (SB00).
Sensor Technology	Infrared
Application	Area monitoring
Refrigerants	All CFC, HCFC, HFC
Detection Limit	CFCs: 5 ppm
Response Time	
Detection Indicator	Liquid crystal display (LCD) readout, RS232C serial link, 2 analog voltage outputs
Power	110/220/240 VAC
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	19-in. rack mount: 7.08 x 19.09 x 16.54 Bench case: 8.07 x 20.47 x 16.93
Weight, lb	48.5
Price	DB00: $11,225; RF00: $11,875; SB00: $5,725

Table B10. CEA Instruments, Inc. Series U detectors.

Parameter	Model		
	F-9200	F-9200P	F-9200 Multipoint
Description	Single-channel, wall-mounted, with fail alarm, check and test switches	Portable with control unit and 12-foot cable with sensor and wand; low battery and charger indicators; built-in battery charger	Multipoint detectors with up to eight channels
Sensor Technology	Solid state	Solid state	Solid state
Application	Area monitoring	Emissions detection	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit			
Response Time	HCFC-22, R-502, HFC-134a: <30 sec; CFC-113, CFC-11, HCFC-123, CFC-12: <90 sec (for 90% full-scale)		HCFC-22, R-502, HFC-134a: <30 sec; CFC-113, CFC-11, HCFC-123, CFC-12: <90 sec (for 90% full-scale)
Detection Indicator	Meter readout, red LED and steady-tone audible alarms, relay contacts	LED and audible alarm	Meter readout, LED alarm, audible alarm (95 db at 39 inches)
Power	115 VAC	3.6V NiCad battery	115 VAC
Battery Discharge Time, hr	N/A		N/A
Size (H x W x D, in.)	6.5 x 4.5 x 2	4.3 x 7.4 x 2.8	4-Channel:10 x 8 x 6 8-Channel:16 x 20 x 7
Weight, lb	1.5 with sensor on controller; 12 with remote sensor	2.0	4-Channel: 7 8-Channel: 40 Remote sensor: 5
Price	$1,295 with sensor on controller; $195 additional for remote sensor	$1,495	2 Channel: $2,850 3 Channel: $3,750 4 Channel: $4,650 5 Channel: $5,475 6 Channel: $6,300 7 Channel: $7,125 8 Channel: $7,950

Cosmos Gas Detection Products

The Cosmos refrigerant detectors use a special "hot wire semiconductor," which is a variation of the standard MOS sensor. The hot wire semiconductor is said to require less operating energy.

Table B11. Cosmos Gas Detection Products.

Parameter	Model	
	XP-316(S)	XP-702S
Description	Handheld, battery-powered leak detector with sampling pump and hot wire semiconductor sensor	Handheld, battery-powered leak detector with sampling pump and hot wire semiconductor sensor; two-gas version available
Sensor Technology	Solid state	Solid state
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	CFC-11, -12; HCFC-22, -123; HFC-134a; R-502	HCFC-22; CFC-113; R-502
Detection Limit	This information was missing from manufacturer literature	Approx. 0.2 oz/yr
Response Time	3 sec max to start of meter deflection with 1-meter sampling tube	3 sec
Detection Indicator	Meter; audible and visual alarms optional [Model XP-316A(S)]	Intermittent audible and flashing LED, which increases in frequency as leak is approached; earphone jack
Power	Four AA-cell batteries	Four AA-cell batteries
Battery Discharge Time, hr	Alkaline batteries: 10	8
Size (H x W x D, in.)	7.5 x 3.3 x 1.6	6.2 x 2.7 x 1.3
Weight, lb	1.5	0.875
Price	$1,320	$650

CPS Products, Inc.

CPS products manufactures two handheld electronic leak detectors using negative corona discharge sensors. The L-790a provides several features not found with the L-780a, including ten sensitivity levels, bar graph display (each segment representing approximately 10 percent change in sensor current), automatic power-off after 15 minutes of operation, and LOCK-OUT mode. The LOCK-OUT mode allows measurement and recording of the highest concentration detected, ignoring lower concentrations until the leak source is found. CPS is also going into production on a single-zone area monitor, the RLM-1, and will soon produce the RLM-8 for monitoring up to eight zones.

Table B12. CPS Products, Inc. portables.

Parameter	Model	
	L-780a Leak-Seeker	L-790a Leak-Seeker
Description	Handheld, portable, battery-powered leak detector with two sensitivity settings	Handheld, portable, battery-powered leak detector with ten sensitivity settings
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	HCFC-134a: 0.5 oz/yr CFC-12: 0.1 oz/yr with highest sensitivity setting	HCFC-134a: <0.5 oz/yr with highest sensitivity setting
Response Time	"Immediate"	"Immediate"
Detection Indicator	LED and variable frequency audible alarms with earphone connection	LED bar graph display and variable frequency audible alarm with earphone connection
Power	Four AA-cell alkaline batteries	Four AA-cell alkaline batteries
Battery Discharge Time, hr	40	30
Size (H x W x D, in.)	7.7 x 2.7 x 1.4	7.7 x 2.7 x 1.4
Weight, lb	1	1
Price	$174.95	$219.95

Table B13. CPS Products, Inc. area monitors.

Parameter	Model	
	RLM-1	RLM-8
Description	Single-channel controller with remote sensor (up to 200 feet from controller) and sensor failure indicator; alarm may be set between 100 and 1000 ppm in steps of 100 ppm (not yet in production)	Eight-channel area monitor (not yet in production)
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants		
Detection Limit		
Response Time		
Detection Indicator		
Power	120/240 VAC	
Battery Discharge Time, hr		
Size (H x W x D, in.)		
Weight, lb		
Price		

Danfoss Automatic Controls

The OzoneSaver is a multisensor programmable system for monitoring of up to eight locations. The unit has RS485 communication to controllers for data collection and dialout capabilities through a remote modem. The sensor has a range of 0 to 3500 ppm and an output voltage of 1 to 4.5 VDC. The prices are trade prices.

Table B14. Danfoss Automatic Controls.

Parameter	Model: OzoneSaver LDS 2000 detector with LD 1000 sensors
Description	Zoned system with 1 to 8 remote LD 1000 factory-calibrated sensors; two alarm levels for each sensor
Sensor Technology	Solid state
Application	Area monitoring
Refrigerants	CFC-11, -12, -113, -114; HCFC-22, -123, -124; HFC-134a; R-502
Detection Limit	
Response Time	
Detection Indicator	LEDs, LCD display, two output relays for each sensor for remote alarming, RS-485 communication, output to shut down exhaust fan for user-defined time period
Power	Detector: 110/230 VAC Sensor: 12 VAC
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	Detector: 15 x 12 x 55 Sensor: 6.5 x 3.5 x 2.12
Weight, lb	
Price	Two sensors: $1,650 Four sensors: $1,935 Six sensors: $2,220 Eight sensors: $2,505

Eagle Creek Technology

Eagle Creek Technology manufactures four continuous and automatic IR-based refrigerant detectors, which differ in the number of zones monitored and in the band-pass.

Table B15. Eagle Creek Technology, halogen-selective detectors.

Parameter	Model	
	HM-1	HM-2
Description	Wall-mounted refrigerant-selective single-zone IR detector	Wall- or rack-mounted refrigerant-selective IR detector for up to seven zones with additional zones optional
Sensor Technology	Infrared	Infrared
Application	Area monitoring	Area monitoring
Refrigerants	All halogen-containing refrigerants including CFC-11, -12; HCFC-22, -123; HFC-134a; R-502	All halogen-containing refrigerants including CFC-11, -12; HCFC-22, -123; HFC-134a; R-502
Detection Limit	10 ppm	10 ppm
Response Time	<10 sec	<10 sec plus 4.8 sec per 100 ft of 1/8-in. sampling line
Detection Indicator	Digital display with red LED and contact closure on alarm	Digital display with red LED and contact closure for each zone on alarm; optional RS-485 and RS-232 interface
Power	115 VAC or 12 VDC	115 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	16 x 14 x 6	19 x 26 x 8
Weight, lb	45	70
Price	$3,995	$5,995

Table B16. Eagle Creek Technology, compound-specific detectors.

Parameter	Model	
	HM-3	HM-4
Description	Wall or rack-mounted compound-specific single-zone IR detector	Wall- or rack-mounted compound-specific IR detector for seven zones with optional additional zones
Sensor Technology	Infrared	Infrared
Application	Area monitoring	Area monitoring
Refrigerants	Factory-set for any single refrigerant	Factory-set for any single refrigerant
Detection Limit	1 ppm	1 ppm
Response Time	<10 sec	<10 sec plus 3.5 sec per 100 ft of 1/4-in. sampling line
Detection Indicator	Digital display with red LED and contact closure for each zone on alarm. Optional RS-485 and RS-232 interface.	Digital display with red LED and contact closure for each zone on alarm; optional RS-485 and RS-232 interface
Power	115 VAC	115 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	19 x 26 x 8	19 x 26 x 8
Weight, lb	60	75
Price	$4,995	$8,695

Eco-Dyne

Eco-Dyne markets a handheld leak detector with a solid state sensor for pinpointing leaks.

Table B17. Eco-Dyne.

Parameter	Model: AN134
Description	Handheld, battery-powered leak detector with charger unit and automobile charging lead; spare battery cassettes and stand-alone charger unit are available
Sensor Technology	Solid state
Application	Pinpointing leaks
Refrigerants	HFC-32, -134a; HCFC-22; others
Detection Limit	10 ppm
Response Time	<0.5 sec for HFC-134a at 20 ppm
Detection Indicator	Set of four LEDs that illuminate as concentration increases; variable-tone and variable-intensity audible signal
Power	Rechargeable battery cassette
Battery Discharge Time, hr	3 hr; 16-hr recharge time
Size (H x W x D, in.)	8.66 x 2.48 x 1.57
Weight, lb	0.815
Price	

Encore Controls, Inc.

Encore manufactures three area detectors using solid state (tin oxide semiconductor) sensors. The OZZIE-1 has four LEDs: orange during warmup, green showing that system is operating correctly, another orange LED during alarm delay following detection of refrigerant, and red during alarm. The two multichannel units, the OZZIE-3 and OZZIE-8, have automatic adjustments that change alarm set points when an increased air flow is detected across a sensor. This permits detection of leaks that might otherwise go undetected.

Table B18. Encore Controls, Inc.

Parameter	Model		
	OZZIE-1	OZZIE-3	OZZIE-4
Description	Wall-mounted with single sensor on unit with three alarm set points	Wall-mounted unit with three hard-wired remote sensors and two alarm set points for each	Wall-mounted unit with three hard-wired remote sensors and two alarm set points for each
Sensor Technology	Solid state	Solid state	Solid state
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	CFC-11, -12, -113; HCFC-22; HFC-134a; R-502	CFC-11, -12, -113; HCFC-22; HFC-134a; R-502	CFC-11, -12, -113; HCFC-22; HFC-134a; R-502
Detection Limit	100 ppm	100 ppm	100 ppm
Response Time	0.5 sec	0.5 sec	0.5 sec
Detection Indicator	Panel alarm LED, analog 0 to 10 VAC output, 0.5 amp relay for remote alarm	Panel alarm LED, analog 0 to 10 VAC output, 0.5 amp relay for remote alarm, and LCD showing which sensor has alarmed	Panel alarm LED, analog 0 to 10 VAC output, 0.5 amp relay for remote alarm and LCD showing which sensor has alarmed
Power	110/208 VAC	110/208 VAC	115 VAC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	8 x 4.5 x 2	8 x 9 x 5	11 x 11.5 x 5
Weight, lb	1	3	4
Price	$495	$1,300	$1,700

ENMET Corporation

ENMET's TG series uses gas-membrane galvanic cell sensors. The BA series consists of portable versions of the TG series detectors. The ISA-44 detectors use solid state sensors. All of the detectors have a variety of sensor types and configurations. ENMET is now evaluating the TG-series monitors for detection of HFC-125, 134a, and 152a.

Table B19. ENMET Corporation MOS sensors, standard enclosures.

Parameter	Model		
	ISA-44	ISA-44-2	ISA-44-OD
Description	Single-channel wall-mounted control unit and remote sensor	Same as ISA-44 except dual-channel monitor	Same as ISA-44-2 but also monitors oxygen
Sensor Technology	Solid state	Solid state	Solid state
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	0 to 2000 ppm CFC-12, -112, -113, -114; HCFC-22; R-500, -502	0 to 2000 ppm CFC-12, -112, -113, -114; HCFC-22; R-500, -502	0 to 2000 ppm CFC-12, -112, -113, -114; HCFC-22; R-500, -502
Detection Limit	250 ppm	250 ppm	250 ppm
Response Time	3 min	3 min	3 min
Detection Indicator	Horn (101 db at 3 meters) and light	Horn (101 db at 3 meters) and light (2 sets)	Horn (101 db at 3 meters) and light (2 sets)
Power	110 or 220 VAC; 12 volts DC (VDC) backup	110 or 220 VAC; 12 VDC backup	110 or 220 VAC; 12 VDC backup
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	Control unit: 16.0 x 8.3 x 5.5; sensor: 6.7 x 4.3 x 3.1	Control unit: 22.5 x 14.3 x 6.3; sensor: 6.7 x 4.3 x 3.1	Control unit: 15.7 x 8.3 x 6.3; sensor: 6.7 x 4.3 x 3.1
Weight, lb	Control unit: 19.8; sensor: 4	Control unit: 50; two sensors: 4 ea	Control unit: 50; two sensors: 4 and 2
Price	$1,245	$2,495	$2,045

Table B20. ENMET Corporation MOS sensors, NEMA-7 enclosures.

Parameter	Model	
	ISA-44E	ISA-44E-2
Description	Similar to ISA-44, but control module has NEMA-7 explosion-proof enclosure for Class I, Division I, Group D hazardous location	Similar to ISA-44-2, but control module has NEMA-7 explosion-proof enclosure for Class I, Division I, Group D hazardous location
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	0 to 2000 ppm CFC-12, -112, -113, -114; HCFC-22; R-500, -502	0 to 2000 ppm CFC-12, -112, -113, -114; HCFC-22; R-500, -502
Detection Limit	250 ppm	250 ppm
Response Time	3 min	3 min
Detection Indicator	Light; alarm relay contact	Light; alarm relay contact
Power	110 or 220 VAC and 12 VDC backup	110 or 220 VAC and 12 VDC backup
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	Control unit: 10.5 x 7.8 x 6.5; sensor: 6.7 x 4.3 x 3.1	Control unit: 10.5 x 7.8 x 6.5; sensor: 6.7 x 4.3 x 3.1
Weight, lb	Control unit: 26; sensor: 4	Control unit: 30; two sensors: 4 ea
Price	$2,345	$3,495

Table B21. ENMET Corporation GMGC sensors, wall/rack-mounted.

Parameter	Model		
	TG-4200	TG-4300	TG-4700
Description	Single-channel wall- or rack-mounted system with sensor, transmitter, controller, and suction-type gas sampler. Multi-channel systems available.	Same as TG-4200 except for refrigerant detected	Same as TG-4200 except for refrigerants detected
Sensor Technology	Gas-membrane galvanic cell	Gas-membrane galvanic cell	Gas-membrane galvanic cell
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	0 to 150 ppm CFC-11, -12, -113; HCFC-22	HCFC-123	0 to 50 ppm HCFC-23; FC-116
Detection Limit	10 ppm	10 ppm	10 ppm
Response Time	<30 sec	<30 sec	<30 sec
Detection Indicator	Analog meter, recorder output, external alarm relay contacts	Analog meter, recorder output, external alarm relay contacts	Analog meter, recorder output, external alarm relay contacts
Power	Controller: 24 VDC power supply (110 VAC); gas sampler sensor: 110 or 220 VAC	Controller: 24 VDC power supply (110 VAC); gas sampler sensor: 110 or 220 VAC	Controller: 24 VDC power supply (110 VAC); gas sampler sensor: 110 or 220 VAC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	Single-channel wall-mount enclosure with controller and power supply: 12 x 12 x 7; gas sampler with transmitter:12 x 12 x 3	Single-channel wall-mount enclosure with controller and power supply: 12 x 12 x 7; gas sampler with transmitter:12 x 12 x 3	Single-channel wall-mount enclosure with controller and power supply: 12 x 12 x 7; gas sampler with transmitter:12 x 12 x 3
Weight, lb	Controller: 1.65; transmitter: 1.76; gas sampler: 8.8	Controller: 1.65; transmitter: 1.76; gas sampler: 8.8	Controller: 1.65; transmitter: 1.76; gas sampler: 8.8
Price	$5,400	$5,400	$5,400

Table B22. ENMET Corporation GMGC sensors, transportable.

Parameter	Model		
	TG-4200 BA	TG-4300 BA	TG-4700 BA
Description	Transportable version of TG-4200	Transportable version of TG-4300	Transportable version of TG-4700
Sensor Technology	Gas-membrane galvanic cell	Gas-membrane galvanic cell	Gas-membrane galvanic cell
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	0 to 150 ppm CFC-11, -12, -113; HCFC-22	HCFC-123	0 to 50 ppm HCFC-23; FC-116
Detection Limit	10 ppm	10 ppm	10 ppm
Response Time	<30 sec for 1/3 full-scale reading	<30 sec for 1/3 full-scale reading	<30 sec for 1/3 full-scale reading
Detection Indicator	Analog meter, red lamp, buzzer, recorder output, external alarm relay contacts	Analog meter, red lamp, buzzer, recorder output, external alarm relay contacts	Analog meter, red lamp, buzzer, recorder output, external alarm relay contacts
Power	110 or 220 VAC and internal battery with charging system	110 or 220 VAC and internal battery with charging system	110 or 220 VAC and internal battery with charging system
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	8 x 8 x 12.5	8 x 8 x 12.5	8 x 8 x 12.5
Weight, lb	12	12	12
Price	$5,200	$5,200	$5,200

EPD Technology Corporation

The EPD-B4 is manufactured to detect any gas whose thermal conductivity differs from that of the ambient air. The EPD-R1 and -R2 GAS CHECK detectors with solid state sensors are produced specifically for refrigerants. The sensor life is 5 years. The EPD-R3 detector is an area monitor.

Table B23. EPD Technology Corporation portables.

Parameter	Model		
	EPD-B4	EPD-R1 GAS CHECK	EPD-R2 GAS CHECK
Description	Battery-operated, handheld multigas leak detector	Battery-operated portable for field use	Rechargeable battery-operated portable with selector for five gas groups
Sensor Technology	Thermal conductivity	Solid state	Solid state
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	CFC-12: 0.4 oz/yr HFC-134a: 0.2 oz/yr	HFC-134a: 0.01 oz/yr; alarm level: 0.5 oz/yr	HFC-134a: 0.01 oz/yr; alarm level: 0.5 oz/yr
Response Time	<1 sec with short probe	1 sec	1 sec
Detection Indicator	Variable frequency audible alarm with speaker and headphone; LCD display	Variable audible alarm and LCD display	Variable audible alarm and LCD display
Power	Four AA-cell batteries	Four AA-cell batteries	Rechargeable (110 or 220 VAC) batteries
Battery Discharge Time, hr	40	8	2
Size (H x W x D, in.)	15 x 2.5 x 2 with nozzle	15 x 2.5 x 2 with nozzle	15 x 2.5 x 2 with nozzle
Weight, lb	1.125	0.88	0.88
Price	$1,895	$1,993	$3,995

Table B24. EPD Technology Corporation monitor.

Parameter	Model: EPD-R3 Gas Alarm
Description	Monitors for halocarbons with flashing red light and buzzer, which stop when gas is no longer sensed. Unit should not be used in the presence of flammable gases.
Sensor Technology	
Application	Area Monitoring
Refrigerants	Halocarbons
Detection Limit	1000 ppm
Response Time	<2 sec
Detection Indicator	Flashing red light and buzzer alarms
Power	115 VAC
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	4 x 4 x 2
Weight, lb	2
Price	$995

Everco Industries

The Everco leak detectors are manufactured for the MAC market; however, the detectors can be used for all halogen-containing refrigerants in other applications. The prices are suggested retail prices.

Table B25. Everco Industries.

Parameter	Model	
	A9767	A9771
Description	Handheld, portable, battery-powered leak detector	Handheld, portable, battery-powered, leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	LED in probe and variable frequency audible alarm	Variable frequency audible alarm
Power	Four AA-cell alkaline batteries	Four AA-cell alkaline batteries
Battery Discharge Time, hr	30	20
Size (H x W x D, in.)	7 x 3 x 1.75	7 x 3 x 1.75
Weight, lb	1.5	1.5
Price	$325.91	$355.69

Extrel Mass Spectrometry

Extrel's Questor 2 and 3 mass spectrometers can be used for ambient air monitoring. The Questor 2 is air conditioned, self-contained, and can be located in adverse ambient conditions. The Questor 3 is more a laboratory instrument. The instruments can be programmed to jump between mass peaks to determine the concentrations of specified gases.

Table B26. Extrel Mass Spectrometry.

Parameter	Model	
	Questor 2	Questor 3
Description	Quadrupole mass spectrometer	Quadrupole mass spectrometer
Sensor Technology	Mass spectra-based	Mass spectra-based
Application	Area monitoring	Area monitoring
Refrigerants	Can be programmed for any refrigerants	Can be programmed for any refrigerants
Detection Limit	10 ppm with Faraday detector or 10 parts per billion (ppb) with multiplier	10 ppm with Faraday detector or 10 ppb with multiplier
Response Time	If a one-second analysis time is used, as many as 12 different locations can be monitored in one minute with an average of four analyses per location	If a 1-second analysis time is used, as many as 12 different locations can be monitored in one minute with an average of four analyses per location.
Detection Indicator	Data can be reported to terminal, printer, or host computer and alarms can be sounded when a component exceeds a given value	Data can be reported to terminal, printer, or host computer and alarms can be sounded when a component exceeds a given value
Power	115 VAC	115 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	80 x 44 x 32	53 x 23 x 34
Weight, lb	1000	600
Price	$120,000	$95,000

Ford Motor Company, Rotunda Equipment Department

Ford Motor Company sells the 161-00010 through its Rotunda Equipment Department, primarily for use in MAC leak detection. Rotunda equipment is sold almost entirely to Ford dealers.

Table B27. Ford Motor Company, Rotunda Equipment Department.

Parameter	Model: 161-00010
Description	Handheld, battery-powered, leak detector
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr
Response Time	"Instantaneous"
Detection Indicator	Audible and visual alarms
Power	Four AA-cell alkaline batteries
Battery Discharge Time, hr	25
Size (H x W x D, in.)	7 x 3 x 1.75
Weight, lb	1
Price	$195

Four Seasons; Big A TempControl; Factory Air

The two detectors shown in Table B28 are sold under three brand names: Four Seasons, Big A TempControl, and Factory Air. Both the 59486-134a Leak Detector and the 59490 Leak Seeker have negative corona discharge sensors and are manufactured primarily for pinpointing leaks in the MAC market; however, the detectors can be used for all refrigerants containing halogen. The 59490 Leak-Seeker detector has ten sensitivity levels, bar graph display (each segment representing approximately 10 percent change in sensor current), and automatic power-off after 15 minutes of operation. The prices given are "user" prices. In the automotive field, the "user" is defined as the dealer or technician.

Table B28. Four Seasons; Big A TempControl; Factory Air.

Parameter	Model	
	59486-134a	59490 Leak-Seeker
Description	Handheld, portable, battery-powered leak detector	Handheld, portable, battery-powered leak detector with ten sensitivity settings
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	HCFC-134a: <0.5 oz/yr with highest sensitivity setting
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	LED and variable frequency audible alarms	LED bar graph display and variable frequency audible alarm with earphone connection
Power	9V alkaline battery	Four AA-cell alkaline batteries
Battery Discharge Time, hr	10	30
Size (H x W x D, in.)	7 x 1.5 x 1.4	7.7 x 2.7 x 1.4
Weight, lb	0.375	1.74
Price	$114.66	$264.60

The Foxboro Company

Foxboro manufactures several single-beam IR spectrometers suitable for detecting refrigerants. Models 1A, 1B2, and 203 are portable (Table B29); models 981, 983, and 984/101 are fixed systems (Table B30). All models have built-in sampling pumps.

Table B29. The Foxboro Company portable detectors.

Parameter	Model		
	Miran 1A	Miran 1B2	Miran 203
Description	Variable wavelength filter, long-pathlength gas cell for ambient air monitoring	Microprocessor-controlled, variable-pathlength cell for ambient air monitoring	For a single compound
Sensor Technology	Infrared	Infrared	Infrared
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	All	All	HCFC-123; other refrigerants possible
Detection Limit		2.25-meter pathlength: CFC-11, 8.0 ppm; HFC-134a, 2.0 ppm. 0.75-meter pathlength: CFC-12, 1.0 ppm; HCFC-21, 0.60 ppm; HCFC-123, 1.9 ppm.	
Response Time			15 sec
Detection Indicator	Meter and output for recorder	Audible alarms, LCD display, analog output	Meter
Power	120 or 220 VAC	120 or 220 VAC (battery charger); NiCad battery	120 or 220 VAC (battery charger); NiCad battery; also AC-only model
Battery Discharge Time, hr	N/A	4	4
Size (H x W x D, in.)	7.5 x 11.1 x 28.4	11 x 9 x 27.8	7.5 x 5.9 x 18.5
Weight, lb	14	30	20
Price	$12,700	$16,990	$6,495

Table B30. The Foxboro Company fixed detector systems.

Parameter	Model		
	Miran 981	**Miran 983**	**Miran 984/101**
Description	Single-beam IR spectrometer ambient air monitoring system for up to five gases from up to 24 remote locations	Single-beam IR spectrometer ambient air monitoring system for a single gas from up to 24 remote locations	Single-beam IR spectrometer ambient air monitoring system for a single gas from a single location
Sensor Technology	Infrared	Infrared	Infrared
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	All	Calibrated for any single refrigerant	Calibrated for any single refrigerant
Detection Limit			
Response Time			<15 sec
Detection Indicator	High/low alarm indicator lamps, printout, alarm and recorder outputs	High/low alarm indicator lamps, printout, alarm output	High/low alarm indicator lamps, audible alarm, meter
Power	120 or 220 VAC	120 or 220 VAC	110 or 220 VAC with battery backup
Battery Discharge Time, hr	N/A	N/A	4
Size (H x W x D, in.)	70.3 x 42.6 x 24.3	70.3 x 42.6 x 24.3	14 x 27 x 13
Weight, lb	350	350	50
Price	Gases Zones Price 1 12 $39,881 2 12 $40,768 3 12 $41,943 4 12 $43,391 5 12 $45,127 1 24 $43,476 2 24 $44,363 3 24 $45,538 4 24 $46,986 5 24 $48,722	Zones Price 1 $28,601 6 $29,205 12 $30,410 24 $33,742	$10,413

Gas Tech, Inc.

Gas Tech manufactures several gas detectors with a range of sensor types. The two halocarbon refrigerant detectors are nondispersive IR-based. The RI-413 is a self-contained portable detector. The wall-mounted monitoring system consists of a 1620 control unit with plug-ins for appropriate remote amplifier/sensor modules.

Table B31. Gas Tech, Inc.

Parameter	Model	
	RI-413	1620
Description	Battery-powered microprocessor-controlled portable NDIR halocarbon monitor with sampling pump, ability to scroll through halocarbon types, and selection of continuous or average readings	Wall-mounted NDIR detector system for monitoring 1 to 4 zones
Sensor Technology	Infrared	Infrared
Application	Emissions detection	Area monitoring
Refrigerants	Most CFC, HCFC, HFC including CFC-11, -12, -113, -114; HCFC-22; HFC-134a; R-502	Most CFC, HCFC, HFC
Detection Limit		
Response Time	90% response in 10 sec	
Detection Indicator	LCD readout of gas concentration; audible alarm when concentration exceeds preset level	Analog meter; dual-level alarms; LED display; relays for remote output; recorder output
Power	Six D-cell alkaline batteries or NiCad batteries	115 or 220 VAC; 12 to 32 VDC standby
Battery Discharge Time, hr	Alkaline: 5; NiCad: 4	N/A
Size (H x W x D, in.)	7.5 x 10 x 4.5	Main control unit: 11.5 x 8.5 x 4.5
Weight, lb	6	13
Price	$3,400	Main control unit: $1,200; CFC amplifier/IR sensor module: $2,250

Gem Products, Inc.

Gem Products, an affiliate of General Electric, markets two handheld, portable, battery-powered leak detectors using negative corona discharge sensors.

Table B32. Gem Products, Inc.

Parameter	Model	
	TM207	TM210
Description	Handheld, battery-powered, leak detector	Handheld, battery-powered leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	Audible and visual alarms	LED and variable frequency audible alarms
Power	Four AA-cell alkaline batteries	9V alkaline battery
Battery Discharge Time, hr	25	10
Size (H x W x D, in.)	7 x 3 x 1.75	7 x 1.5 x 1.4
Weight, lb	1	0.375
Price	$140.00	$89.99

General Analysis Corporation

The SAM-I Gas Analyzer uses dual wavelength IR detection with interference filters. As sold, the detector has only one channel; however, an auxiliary system allowing air sampling from up to six different locations is available. The instrument uses a filter/detector combination to select wavelengths characteristic of the gas to be detected. The detector can be used for any refrigerant by changing one part and recalibrating.

Table B33. General Analysis Corporation.

Parameter	Model: SAM-I
Description	Dual-wavelength IR detection with interference filters, three-level alarm, and automatic zero.
Sensor Technology	Infrared
Application	Area monitoring
Refrigerants	All CFC, HCFC, HFC
Detection Limit	1 ppm
Response Time	20 seconds at 2 liters/minute flow rate and 100-ft sampling line
Detection Indicator	Digital display; relays for alarm activation
Power	120 or 240 VAC
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	16 x 16 x 7
Weight, lb	33
Price	$4,100; optional 6-point sampling system: $6,500 additional

Genesis International, Inc.

All of the Sherlock detectors have a transformer that plugs directly into a standard 110 VAC receptacle. The Sherlock Junior puts out only an analog signal.

Table B34. Genesis International, Inc.

Parameter	Model		
	Sherlock 100	Sherlock 400	Sherlock Junior
Description	1 channel, 2 models (wall- and rack-mounted); alarm log retains last alarm level and alarm time; remote sensor	4-channel area monitor with four remote sensors; alarm log retains last 32 alarms (location, level, time, date)	Self-contained area monitor with built-in sensor and 3 sensitivity levels; analog signal is only output
Sensor Technology	Solid state	Solid state	Solid state
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	Kit 88-0056: CFCs and HCFCs; Kit 88-0058: HFCs	Kit 88-0050: CFCs and HCFCs; Kit 88-0060: HFCs	
Detection Limit			
Response Time			
Detection Indicator	Digital readout; light and audible beeper alarms; alarm relay	Digital readout; light alarm; alarm relay; communications port	4 to 20 mA output; no internal alarms
Power	110 VAC	110 VAC	110 VAC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	Control: 4 x 6 x 1.6 Sensor: 2 x 3 x 1.5	Control: 6.125 x 9.625 x 2.325 Sensor: 1.5 x 2 x 2	4 x 2 x 1.5
Weight, lb	1.5	5	0.5
Price	$350	$1,050	$110

Geopal System A/S

Geopal manufactures a wide assortment of rack-mounted detectors for area monitoring and portable detectors for pinpointing leaks. All operate with solid state sensors. The detectors are acceptable for any refrigerants; however, the company specifically indicates their use for CFC-11, CFC-12, HCFC-21, HCFC-22, CFC-113, HCFC-123, HFC-134a, and R-502. Geopal also produces a variety of alarm systems for area monitors.

GOW-MAC Instrument Company

GOW-MAC manufactures a wide variety of gas chromatography equipment in addition to the 21-250 leak detector, which uses a thermal conductivity sensor. This instrument is not specifically manufactured for refrigerants, but it can be used for any gas whose thermal conductivity differs from that of the ambient air.

Table B35. GOW-MAC Instrument Company.

Parameter	Model: 21-250
Description	Portable gas leak detector with thermal conductivity sensor, integral diaphragm pump, two sensitivity ranges
Sensor Technology	Thermal conductivity
Application	Pinpointing leaks
Refrigerants	Any refrigerant whose thermal conductivity differs from ambient air
Detection Limit	0.6 oz/yr (1.1×10^{-4} cm^3/sec)
Response Time	<2 sec
Detection Indicator	Analog meter, variable frequency audible signal
Power	115/230 or 9V rechargeable lead/acid gel battery
Battery Discharge Time, hr	4
Size (H x W x D, in.)	3.625 x 10.75 x 8.25
Weight, lb	9
Price	$995

Hitech Instruments

Hitech Instruments manufactures small, portable battery-powered detectors for pinpointing leaks using negative corona discharge sensors. The company also manufactures detectors for private branding by several other companies.

Table B36. Hitech Instruments.

Parameter	Model		
	HI 134a	HI 300 TEL	HI 400-A TEL
Description	Handheld, battery-powered leak detector	Handheld, battery-powered leak detector	Handheld, battery-powered, leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	<0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"	"Instantaneous"
Detection Indicator	LED and variable-frequency audible alarms	LED and variable-frequency audible alarms	Audible and visual alarms
Power	9V alkaline battery	Four AA-cell alkaline batteries	Four AA-cell alkaline batteries
Battery Discharge Time, hr	10	40	25
Size (H x W x D, in.)	7 x 1.5 x 1.4	7 x 3 x 1.75	7 x 3 x 1.75
Weight, lb	0.375	1.5	1
Price	$99.95	$169.00	$250.00

Imperial Eastman

Imperial Eastman manufactures four portable leak detectors which differ in the refrigerants detected and the presence or absence of a visual leak display. The "M" designation indicates that it will serve for multiple refrigerants including HFCs. Otherwise, the detector is for CFCs and HCFCs only. The "L" designation indicates that the detector has an LED leak size indicator.

Table B37. Imperial Eastman CFC/HCFC refrigerant detectors.

Parameter	Model	
	Annie II A2-007	Annie II A2-007L
Description	Portable battery-operated leak detector with probe attached to 36-in. coiled cord; pump in probe	Portable battery-operated leak detector with probe attached to 36-in. coiled cord; pump in probe
Sensor Technology		
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC	All CFC, HCFC
Detection Limit	<0.40 oz/yr	<0.40 oz/yr
Response Time		
Detection Indicator	Audible beeping signal increasing in speed and frequency as leak source approached	Audible beeping signal increasing in speed and frequency as leak source approached; seven LED leak size indicators
Power	Two 1.5V C-cell batteries	Two 1.5V C-cell batteries
Battery Discharge Time, hr		
Size (H x W x D, in.)		
Weight, lb		
Price	$205.17	$216.32

Table B38. Imperial Eastman CFC/HCFC/HFC refrigerant detectors.

Parameter	Model	
	Annie II A2-007M	Annie II A2-007ML
Description	Portable battery-operated leak detector with probe attached to 36-in. coiled cord; pump in probe	Portable battery-operated leak detector with probe attached to 36-in. coiled cord; pump in probe
Sensor Technology		
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	Switch between CFC/HCFC and HFC refrigerants	Switch between CFC/HCFC and HFC refrigerants
Detection Limit	<0.40 oz/yr	<0.40 oz/yr
Response Time		
Detection Indicator	Audible beeping signal increasing in speed and frequency as leak source approached	Audible beeping signal increasing in speed and frequency as leak source approached; seven LED leak size indicators
Power	Two 1.5V C-cell batteries	Two 1.5V C-cell batteries
Battery Discharge Time, hr		
Size (H x W x D, in.)		
Weight, lb		
Price	$232.50	$252.41

International Sensor Technology

International Sensor Technology (IST) manufactures four types of detectors for refrigerants: wall-mounted, rack/panel-mounted, portable, and a wireless remote link system. A number of different types of sensors are available. All are solid state devices and are interchangeable between models. IST has a warranty of 3 years on their sensors. The heater temperature is adjustable, allowing control of sensitivity and selectivity. A thermistor allows temperature regulation.

The four wall-mounted detectors differ in the number of channels available, as do the four rack-mounted detectors. Each channel can be used for a separate monitoring area and/or a separate gas. Two battery-powered portable leak detectors are also available.

Technical data for the remote link system are not shown in the following tables because this system is custom configured and can vary significantly. The remote link

system can use AC power lines to incorporate hundreds of sensors into one system. Complete remote link systems, including an IBM-compatible PC with software for data archiving, report generation, calibration, etc., can be furnished.

Table B39. International Sensor Technology wall-mounted detectors.

Parameter	Model		
	AG2000	AG2002	AG2003; AG2004
Description	Single-channel detector with explosion proof version available (AG2200)	Two-channel version of AG2000	Three-channel (AG2003) and four-channel (AG2004) versions of AG2000
Sensor Technology	Solid state	Solid state	Solid state
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit			
Response Time	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec
Detection Indicator	Relays for malfunction, warning, and alarm; recorder output	Relays for malfunction, warning, and alarm provided; recorder output	Relays for malfunction, warning, and alarm provided; recorder output
Power	110/220 VAC or 12/24 VDC	110/220 VAC or 12/24 VDC	110/220 VAC or 12/24 VDC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	11.5 x 9.2 x 4.0	13.5 x 11.2 x 5.3	15.5 x 13 x 6.3
Weight, lb	10	15	20.3
Price	$1,660	$2,785	AG2003: $3,805 AG2004: $4,580

Table B40. International Sensor Technology rack/panel-mounted, single/dual-channel detectors.

Parameter	Model	
	AG3100	AG3102
Description	Single-channel instrument	Two-channel version of AG3100
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit		
Response Time	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec
Detection Indicator	Warn and alarm LED displays and relays; analog meter	Warn and alarm LED displays and relays; analog meter
Power	110/220 VAC or 12/24 VDC	110/220 VAC or 12/24 VDC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	5.25 x 2.8 x 10.62	5.25 x 2.8 x 13.55
Weight, lb	4	5
Price	$1,445	$2,490

Table B41. International Sensor Technology rack/panel-mounted, four/eight-channel detectors.

Parameter	Model	
	AG40	AG80, AG80R
Description	Up to four channels available	Up to eight channels available; AG80R has two relays for each channel
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit		
Response Time	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec
Detection Indicator	Warn and alarm LED displays and relays; analog meter	Warn and alarm LED displays and relays; analog meter
Power	110/220 VAC or 12/24 VDC	110/220 VAC or 12/24 VDC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	5.25 x 4.20 x 18	5.25 x 19 x 18
Weight, lb	11.5	23
Price	$4,595	$9,030; Model AG80R: $9,910

Table B42. International Sensor Technology portables.

Parameter	Model	
	AG5000	AG5100
Description	Portable battery-powered leak detector with built-in battery charger and optional pump	Handheld battery-powered leak detector
Sensor Technology	Solid state	Solid state
Application	Emissions detection	Emissions detection
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit		
Response Time	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec	Typically 60 sec for full-scale response; however, time to alarm can be significantly lower, 10-15 sec
Detection Indicator	Audible alarm, analog meter	Audible alarm, analog meter
Power	One 9.6V plus two D-cell batteries	One 9.6V plus two D-cell batteries
Battery Discharge Time, hr	10	8 to 10
Size (H x W x D, in.)	5.3 x 7.8 x 4.2	2.0 x 3.0 x 6.0
Weight, lb	5	1.8
Price	$1,375	$1,375

Ion Track Instruments, Inc.

Ion Track manufactures three portable refrigerant leak detectors. The Leakmeter 120 consists of a portable console attached to a handheld detector. Readouts can be stored and the results dumped through an RS-232 interface to a printer or computer. A replaceable 600-cm^3 argon cylinder (providing 12 hours of continuous use) is required for the Leakmeter 120.

Table B43. Ion Track Instruments, Inc.

Parameter	Model		
	Leakfinder 134	**Leakmeter 120**	**Model 96 Leakseeker**
Description	Portable line-powered detector with pump	Handheld electron capture leak detector with direct readout of leak rate or concentration; battery or AC power	Battery-operated handheld leak detector with thermal conductivity sensor and low flow fan for sampling
Sensor Technology	Solid state	Electron capture	Thermal conductivity
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	Selectable between HFC and CFC/HCFC	All CFC, HCFC, HFC	Any refrigerant whose thermal conductivity differs from ambient air
Detection Limit	HFC-134a: 0.02 oz/yr		CFC-12: 0.07 oz/yr (1.2×10^{-5} cm^3/sec)
Response Time	<1 sec	<1 sec	<1 sec
Detection Indicator	Analog bar graph display and digital leak rate readout with alarm	LCD readout, audible and visual alarms	LCD readout, audible and visual alarms
Power	110 or 220 VAC	110 or 220 VAC; 12V rechargeable battery	Four 1.5V AA-cell batteries
Battery Discharge Time, hr	N/A	8	14
Size (H x W x D, in.)	8 x 13 x 5.8	Console: 15 x 19 x 8.5	Case: 10 x 14 x 3.5
Weight, lb	22.5	43 (packing weight)	1.5
Price	$4,700	$10,955	$1,695

J and N Associates, Inc.

J and N Associates produces two handheld battery-operated leak detectors—one using a solid state sensor; the other, a negative corona discharge sensor. The Sensit RFC, which uses a diaphragm pump, is specifically for refrigerants.

Table B44. J and N Associates, Inc.

Parameter	Model	
	Sensit HXG-1	Sensit RFC
Description	Handheld battery-operated leak detector with green ready light, alarm set, and tick rate adjust	Handheld battery-operated leak detector with diaphragm pump, green ready light, alarm set, and tick rate adjust
Sensor Technology	Solid state	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	10 ppm	0.1 oz/yr
Response Time	<1 sec	<1 sec
Detection Indicator	Variable tick rate audible alarm and flashing red alarm light with earphone jack	Variable tick rate audible alarm and flashing red alarm light with earphone jack
Power	Three C-cell alkaline batteries	Three C-cell alkaline batteries
Battery Discharge Time, hr	8	16
Size (H x W x D, in.)	10 x 3.5 x 1.6	10 x 3.5 x 1.6
Weight, lb	1.3	1.3
Price	$274	$347

Leybold-Inficon, Inc.

The battery-powered handheld D-Tek is the newest of the Leybold-Inficon detectors. The AC-powered HLD 3000 and 4000 detectors use a control unit connected to a handheld probe with a 7.5-ft or 15-ft cable. The 4000 Series A is designed for non-chlorine-containing refrigerants (HFCs); the Series C detects CFCs and HCFCs. The AC-powered units have built-in calibration gases and pumps in the probes.

Table B45. Leybold-Inficon, Inc.

Parameter	Model		
	D-Tek	HLD 3000	HLD-4000 Series A and Series C
Description	Handheld leak detector with flexible 12-inch probe	AC-powered portable detector with control unit, cable, and probe	AC-powered portable detector with control unit, cable, and probe
Sensor Technology	Heated diode	Heated diode	Heated diode
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	CFC and HCFC	Series A: HFCs Series C: CFCs, HCFCs
Detection Limit	0.25 oz/yr		
Response Time	<0.5 sec	<0.5 sec	<0.5 sec
Detection Indicator	Variable intermittent audible alarm; string of LEDs that light progressively to show leak magnitude	LED display, 140-db alarm, 2 alarm relays, RS-232C communications connection	LED signal, 140-db alarm, RS-232C communications connection
Power	NiCad battery or AC operation with recharger	120 and 240 VAC	120 and 240 VAC
Battery Discharge Time, hr	3	N/A	N/A
Size (H x W x D, in.)	8.81 x 2.30 x 2.65 plus 12-in. probe	Control: 8.5 x 9 x 10	Control: 8.5 x 9 x 10
Weight, lb	1.28	Control unit and probe: 15	Control unit and probe: 15
Price	$375	$4,000	Series A: $4,500 Series C: $4,150

MAC Tools, Inc.

MAC Tools, Inc. markets four battery-operated, portable leak detectors for pinpointing refrigerant leaks. All detectors use negative corona discharge sensors.

Table B46. MAC Tools, Inc. AC134AJR and AC134AP detectors.

Parameter	Model	
	AC134AJR	AC134AP
Description	Handheld, battery-powered leak detector	Portable battery-powered leak detector with 19-in. probe
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	LED and variable frequency audible alarms	Flashing light; audible alarm
Power	9V alkaline battery	Four AA-cell 1.5V alkaline batteries or AC operation
Battery Discharge Time, hr	10	40
Size (H x W x D, in.)	7 x 1.5 x 1.4	3.125 x 7 x 1.75
Weight, lb	0.375	1.5
Price	$99.95	$207.95

Table B47. MAC Tools, Inc. AC5550 and AC5650 detectors.

Parameter	Model	
	AC5550 Multi-Gas Leak Detector	**AC5650 Multi-Gas Leak Detector**
Description	Battery-powered handheld portable with pump and switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency with increasing gas concentration; probe with 36-in. coiled cord	Battery-powered handheld portable with pump and switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency with increasing gas concentration; seven LED visual signals indicate leak size; probe with 36-in. coiled cord
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	Variable frequency audible signal	Variable frequency audible and LED signals
Power	3 VDC (two C-cell alkaline batteries)	3 VDC (two C-cell alkaline batteries)
Battery Discharge Time, hr	50	50
Size (H x W x D, in.)	8 x 3 x 1.8	8 x 3 x 1.8
Weight, lb	1.25	1.25
Price	$189.95	$209.95

Macurco, Inc.

The four Macurco detectors all mount in standard 4 x 4 electrical boxes and differ primarily in output (relay, audible alarm, or analog current/voltage).

Table B48. Macurco, Inc. detectors with relay outputs.

Parameter	Model	
	FD-11	FD-12
Description	Area monitor mounts in standard 4 x 4 in. electrical box	Area monitor mounts in standard 4 x 4 in. electrical box
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	CFC-11, -12, -113; HCFC-21, -22; R-502 (must specify refrigerant)	CFC-11, -12, -113; HCFC-21, -22; R-502 (must specify refrigerant)
Detection Limit		
Response Time		
Detection Indicator	One relay	Two relays
Power	12 or 24 VAC or DC	12 or 24 VAC or DC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	4.5 x 4.5 x 1.75	4.5 x 4.5 x 1.75
Weight, lb	1 (shipping weight)	1 (shipping weight)
Price	$150	$225

Table B49. Macurco, Inc. detectors with audible alarm or current/voltage output.

Parameter	Model	
	FD-21	FD-12
Description	Area monitor mounts in standard 4 x 4 in. electrical box	Area monitor mounts in standard 4 x 4 in. electrical box with green LED showing normal operating condition
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	CFC-11, -12, -113; HCFC-21, -22; R-502 (must specify refrigerant)	CFC-11, -12, -113; HCFC-21, -22; R-502 (must specify refrigerant)
Detection Limit		
Response Time		
Detection Indicator	Audible alarm, 85 db at 10 ft	Analog 4 to 20 mA and 1 to 5 volt output; red LED alarm
Power	120 vac	12 or 24 VAC or DC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	4.5 x 4.5 x 1.75	4.5 x 4.5 x 1.75
Weight, lb	1 (shipping weight)	1 (shipping weight)
Price	$150	$230

Matheson Safety Products

Matheson Safety Products provides three off-the-shelf units having refrigeration detection capabilities. In addition, custom gas detection systems having a wide range of possible configurations are available.

Table B50. Matheson Safety Products portable detectors.

Parameter	Model		
	8057	8065 Leak Hunter	8067
Description	Portable thermal conductivity detector	Portable thermal conductivity detector	Portable thermal conductivity detector
Sensor Technology	Thermal conductivity	Thermal conductivity	Thermal conductivity
Application	Emissions detection	Pinpointing leaks	Pinpointing leaks
Refrigerants	CFC-12, others	CFC-12, others	CFC-12, others
Detection Limit	CFC-12: 100 oz/yr (1 cm^3/min)	CFC-12: 0.001 oz/yr (1.2×10^{-5} cm^3/min)	0.0006 oz/yr (6×10^{-6} cm^3/min)
Response Time	5 to 10 sec	1 sec without extension probe; 20 sec with extension	1 sec without extension probe; 9 sec with extension
Detection Indicator	Intermittent buzzer; LED lamp	LCD bar graph; audible alarm	LCD digital display
Power	Four AA-cell NiCad rechargeable batteries	Four 1.5V NiCad rechargeable batteries	Four 1.5V alkaline batteries
Battery Discharge Time, hr	3	8	20
Size (H x W x D, in.)	6.1 x 2.7 x 1.2 w/o probe		15 x 2.4 x 2
Weight, lb	0.875	1.5	1.125
Price	$1,450	$1,525	$1,850

Table B51. Matheson Safety Products custom systems.

Parameter	Model
	Custom Gas Detection Systems
Description	Available in wall-mounted, rack-mounted, portable, multichannel, and computerized systems
Sensor Technology	Solid state
Application	Area monitoring
Refrigerants	CFC-11, -12, -113, -114
Detection Limit	50 ppm
Response Time	30 to 60 sec for 80% full-scale (typical)
Detection Indicator	Analog meter
Power	115 VAC, 220 VAC, or NiCad batteries
Battery Discharge Time, hr	8 to 10
Size (H x W x D, in.)	Varies
Weight, lb	Wall-mounted: 10 to 23; portable: 1.75 to 5
Price	Approx $1,500 per detection point

Mine Safety Appliances Company

Mine Safety Appliances (MSA) detectors use metal oxide semiconductor (MOS) or IR photoacoustic sensors. All are for area monitoring. Only the Chillgard detectors have multiple zone monitoring capabilities. Prices depend upon calibration and options. Sample prices are listed in Tables B52 and B53.

Table B52. Mine Safety Appliances Company Chillgard brand detectors.

Parameter	Model	
	Chillgard	Chillgard IR
Description	Four-channel area monitor with solid state (MOS) sensor	Detection system with photoacoustic IR sensor, pump (100 ft tubing max); multipoint sequencer adds up to six monitoring points
Sensor Technology	Solid state	Infrared
Application	Area monitoring	Area monitoring
Refrigerants	482609 sensor: CFC-12 802602 sensor: HCFC-22; HFC-134a	HCFC-123; HFC-134a; other HCFCs, HFCs
Detection Limit		To 1 ppm
Response Time	30 sec maximum	90% of final reading in 70 sec
Detection Indicator	Audible and visible alarms, relays for remote alarm	LCD display, LEDs and relays for each alarm level
Power	115 or 220 VAC	120 or 240 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	Monitor: 8.25 x 6.25 x 4.25 Sensor: 0.75 diameter, 2.5 long	17.5 x 14 x 6
Weight, lb	7	44
Price	Unit: $1,340; sensor: $230	Single-channel: $4,125; with six-point sequencer: $7,625

Table B53. Mine Safety Appliances Company Lira brand detectors.

Parameter	Model		
	Lira 202	Lira 3000	Lira 3250
Description	Five model variations (202, 202X, 202S, 202SX, 202FR) provide single-channel detection systems with photoacoustic NDIR sensors	Single-channel detection system with photoacoustic NDIR sensors	Single-channel IR detector with pump and optional remote sampling capability
Sensor Technology	Infrared	Infrared	Infrared
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit			
Response Time	90% of final reading in 0.4 to 5 sec depending on specific model	90% of final reading in 5 sec	95% of step change in 5 sec
Detection Indicator	Analog meter, recorder output	Analog meter, 3 set point alarms, optional LED digital display	Analog meter, visible alarm with output relays (two levels)
Power	115 VAC	105, 120, or 220 VAC	120 or 240 VAC; optional battery backup
Battery Discharge Time, hr	N/A	N/A	Battery backup: 4
Size (H x W x D, in.)	202: 12.5 x 19 x 13 202X: 14 x 20.4 x 18 202S: 9 x 37.5 x 12 202SX: 12.4 x 39.5 x 14.5 202FR: 12.5 x 19 x 13	8.5 x 11 x 21.875	19 x 14 x 9
Weight, lb	202: 76; 202X: 105; 202S: 60; 202SX: 210; 202FR: 76	44	
Price	$6,850	$5,100	$2,915

Motors & Armatures, Inc.

The Motors & Armatures MARS H-10G detector comes with a reference leak.

Table B54. Motors & Armatures, Inc.

Parameter	Model: MARS H-10G
Description	Line-powered portable with internal pump and built-in calibration reference
Sensor Technology	Heated diode
Application	Pinpointing leaks
Refrigerants	CFC-12; HCFC-22, -123; HFC-134a; R-502; others
Detection Limit	CFC, HCFC: 0.05 oz/yr HFC: 0.5 oz/yr
Response Time	0.5 sec
Detection Indicator	80-db horn, flashing light alarms
Power	115 VAC
Battery Discharge Time, hr	M/A
Size (H x W x D, in.)	5 x 8.5 x 2.7
Weight, lb	3.4
Price	

Murray Temperature Control

The Murray leak detectors are manufactured for the MAC market; however, the detectors can be used for all halogen-containing refrigerants in other applications.

Table B55. Murray Temperature Control.

Parameter	Model	
	209907	209909
Description	Handheld, portable, battery-powered leak detector	Handheld, portable, battery-powered, leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	LED in probe and variable-frequency audible alarm	Variable-frequency audible alarm
Power	Four AA-cell alkaline batteries	Four AA-cell alkaline batteries
Battery Discharge Time, hr	30	20
Size (H x W x D, in.)	7 x 3 x 1.75	7 x 3 x 1.75
Weight, lb	1.5	1.5
Price	$325.91	$355.69

Pacer Industries, Inc.

Pacer markets two small, portable battery-powered detectors with negative corona discharge sensors for pinpointing leaks.

Table B56. Pacer Industries, Inc.

Parameter	Model	
	LD1	LD5
Description	Handheld, battery-powered leak detector	Handheld, battery-powered leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	0.5 oz/yr	0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	LED and variable frequency audible alarms	LED and variable frequency audible alarms
Power	Four AA-cell alkaline batteries	9V alkaline battery
Battery Discharge Time, hr	40	20
Size (H x W x D, in.)	7 x 3 x 1.75	7 x 1.5 x 1.4
Weight, lb	1.5	0.375
Price	$129	$107

PAMA Electronics Company, Ltd.

This Israeli firm is represented in the United States by A.D.D.M. International, Inc. (see Appendix C for a list of companies contacted in this report). Their GAS ALARM refrigerant detectors use Figaro MOS sensors. The two PAMA detectors differ only in refrigerants detected.

Table B57. PAMA Electronics Company, Ltd.

Parameter	Model	
	GHD 2070	GHD 2075
Description	Wall-mounted system for area monitoring with MOS sensor and optional remote sensor	Wall-mounted installed system for area monitoring with MOS sensor and optional remote sensor
Sensor Technology	Solid state	Solid state
Application	Area monitoring	Area monitoring
Refrigerants	HCFC-21, -22	CFC-11, -12, -113; HCFC-22; HFC-134a; R-502
Detection Limit	100 ppm HCFC-22	100 ppm HCFC-22 or R-502
Response Time	90% response in 1 min	90% response in 1 min
Detection Indicator	LED visual and 85 db audible alarms	LED visual and 85 db audible alarms
Power	110/220 VAC	110/220 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	6.1 x 5.7 x 2.3	6.1 x 5.7 x 2.3
Weight, lb	1.5	1.5
Price	$450	$450

Photovac International, Inc.

The Photovac 10S PLUS portable gas chromatograph uses a photoionization detector (PID) with a standard 10.6 electron-volt (eV) UHF-excited electrodeless discharge tube. Other lamps are available. Computerization allows setting of parameters and storage/retrieval of data. Automatic, unattended monitoring is possible. Two adjustable alarm levels are available.

Table B58. Photovac International, Inc.

Parameter	Model: 10S PLUS
Description	Computerized, portable gas chromatograph with a PID
Sensor Technology	Gas chromatography
Application	Area monitoring
Refrigerants	CFC-11, -12, -13, -14, -113, -114, -114a; HCFC-21, -22, -124, -141b; HFC-134, -134a, -152a
Detection Limit	High ppb range
Response Time	<5 min
Detection Indicator	Internal audible alarm, output for external alarm, LC display, chart recorder output
Power	10 to 18 VDC
Battery Discharge Time, hr	7
Size (H x W x D, in.)	6.0 x 18.3 x 14.4
Weight, lb	28
Price	$19,500

Ritchie Engineering Company, Inc.

Ritchie Engineering Company Inc. markets three handheld, portable, battery-powered detectors for pinpointing leaks using negative corona discharge sensors.

Table B59. Ritchie Engineering Company, Inc.

Parameter	Model		
	69320	69300	69425
Description	Handheld, battery-powered leak detector	Handheld, battery-powered leak detector	Handheld, battery-powered, leak detector
Sensor Technology	Negative corona discharge	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.5 oz/yr	<0.5 oz/yr	<0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"	"Instantaneous"
Detection Indicator	LED and variable-frequency audible alarms	LED and variable-frequency audible alarms	Audible and visual alarms
Power	9V alkaline battery	Four AA-cell alkaline batteries	Four AA-cell alkaline batteries
Battery Discharge Time, hr	10	40	25
Size (H x W x D, in.)	7 x 1.5 x 1.4	7 x 3 x 1.75	7 x 3 x 1.75
Weight, lb	0.375	1.5	1
Price	$99.95	$169.00	$169.00

Robinair Division, SPX Corporation

Robinair manufactures three handheld leak detectors primarily for the MAC sector. All use a negative corona discharge sensor and have an audible alarm which varies in frequency as a leak is approached.

Table B60. Robinair Division, SPX Corporation.

Parameter	Model	
	14970B	W13480
Description	Handheld, battery-operated leak detector with pump	Handheld, battery-operated leak detector with pump
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	Primarily CFCs and HCFCs; can be used for HFCs at higher leak rates	Switch between CFC/HCFC and HFC refrigerants
Detection Limit	As low as 0.5 oz/yr	0.40 oz/yr
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	Variable-frequency audible alarm	Variable-frequency audible alarm
Power	Four AA-cell batteries	Four AA-cell batteries
Battery Discharge Time, hr	50	60
Size (H x W x D, in.)	7 x 3 x 1.5	7 x 3 x 1.5
Weight, lb	1 (without batteries)	1
Price	$197.05	$250.00

Sensidyne, Inc.

Sensidyne does not market a detector specifically for refrigerants; however, their portable flame ionization detector (FID) will detect halocarbons. The FID is field-portable and is carried by a shoulder strap. A sampling pump draws air from a hand-held probe and passes it to a hydrogen flame. The unit contains a small hydrogen cylinder to maintain the flame. The FID has two ranges—0 to 1000 ppm and 0 to 10,000 ppm—and can be ordered with ten times normal sensitivity. The detector is also available in a gas chromatography kit with a portable chart recorder.

Table B61. Sensidyne, Inc.

Parameter	Model: 7012111-1
Description	Portable flame ionization detector kit with hydrogen cylinder, standard probe, carrying sling, battery charger, carrying case.
Sensor Technology	Flame ionization
Application	Emissions detection
Refrigerants	
Detection Limit	
Response Time	2 to 3 sec
Detection Indicator	Analog concentration meter and audible, variable frequency alarm with earphone socket
Power	Rechargeable lead acid batteries
Battery Discharge Time, hr	15
Size (H x W x D, in.)	
Weight, lb	6.75
Price	

SenTech Corporation

SenTech's models 1030 and 1033 are just being introduced. Both use a sampling pump rather than the fan used by the Model 1020 detector. The System 2000 uses a pump to draw samples through up to 500 feet of tubing. All prices given are trade list prices.

Table B62. SenTech Corporation fixed single-zone detectors.

Parameter	Model		
	System 1000, Model 1020	System 1000, Model 1030	System 2000, Model 1033
Description	Single-zone, self-contained, wall-mounted unit with fan for gas sampling	Similar to Model 1020 except with pump for sampling through up to 10 feet of 3/8-inch tubing	Similar to model 1030 but has three factory-set alarm levels at 7 ppm, 30 ppm, and 100 ppm
Sensor Technology	Heated diode	Heated diode	Heated diode
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	CFC-11, -12; HCFC-22, -123; R-500, -502, others	CFC-11, -12; HCFC-22, -123; R-500, -502, others	CFC-11, -12; HCFC-22, -123; R-500, -502, others
Detection Limit	As low as 1 ppm	As low as 1 ppm	As low as 1 ppm
Response Time	7 sec to 3 min depending on refrigerant concentration	7 sec to 3 min depending on refrigerant concentration	7 sec to 3 min. Each zone sampled for 1 min; max delay of 16 min with 16 zones
Detection Indicator	Analog meter with single-level alarm light and alarm relays	Analog meter with single-level alarm light and alarm relays	Analog meter with three-level alarm lights and alarm relays
Power	115 or 220 VAC	115 or 220 VAC	115 or 220 VAC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	15 x 11.5 x 4.7	15 x 11.5 x 4.7 w/o cart	24 x 24 x 8
Weight, lb	17	60 with cart	70
Price	$5,170		$5,770

Table B63. SenTech Corporation portable and multiple-zone units.

Parameter	Model	
	System 1000, Model 1300	System 2000, Model 2004
Description	Portable version of Model 1020 with mobile cart	4-, 8-, or 16-zone units with sequential sampling
Sensor Technology	Heated diode	Heated diode
Application	Area monitoring	Area monitoring
Refrigerants	CFC-11, -12; HCFC-22, -123; R-500, -502, others	CFC-11, -12; HCFC-22, -123; R-500, -502, others
Detection Limit	As low as 1 ppm	As low as 1 ppm
Response Time	7 sec to 3 min depending on refrigerant concentration	7 sec to 3 min. Each zone sampled for 1 min; max delay of 16 min with 16 zones
Detection Indicator	Analog meter and alarm light with alarm relays	Analog meters and alarm lights for each zone with alarm relays
Power	115 or 220 VAC	115 or 220 VAC
Battery Discharge Time, hr	N/A	N/A
Size (H x W x D, in.)	15 x 11.5 x 4.7 w/o cart	24 x 24 x 8
Weight, lb	60 with cart	70
Price	$5,832	4 zones: $9,700 8 zones: $11,200 16 zones: $14,200

Servomex Company

Servomex makes a wide range of IR-based gas detectors. The company does not specifically make a dedicated detector for refrigerants, but like many IR companies, Servomex can configure their instruments to detect refrigerants. The configuration cost could be relatively high. The Servomex PA404 infrared analyzer is a portable instrument, which has been used to pinpoint leaks.

Table B64. Servomex Company.

Parameter	Model: PA404
Description	Portable infrared analyzer with optional sampling pump
Sensor Technology	Infrared
Application	Emissions detection
Refrigerants	0-500 ppm CFC-12 and other CFC, HCFC, HFC; must be configured
Detection Limit	
Response Time	5 sec or longer
Detection Indicator	3-digit LCD in ppm or percent; recorder output; alarm relay
Power	Integral 16V, 2.5 amp-hr battery pack with built-in recharger (110-120 VAC or 220-250 VAC)
Battery Discharge Time, hr	5
Size (H x W x D, in.)	7.25 x 7.8 x 15.3 with shortest cell 7.25 x 7.8 x 27.2 with longest cell
Weight, lb	12.1
Price	

Siemens Industrial Automation, Inc.

Siemens does not specifically make a dedicated detector for refrigerants, but can configure their instruments to detect specific refrigerants.

Table B65. Siemens Industrial Automation, Inc.

Parameter	Model		
	ULTRAMAT 5	ULTRAMAT 21	ULTRAMAT 22
Description	NDIR detector for area monitoring	Single-channel (one component) single-beam NDIR gas analyzer with pump for area monitoring	Two-channel (two components) single-beam NDIR gas analyzer with pump for area monitoring
Sensor Technology	Infrared	Infrared	Infrared
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	Configurable	Configurable	Configurable
Detection Limit			
Response Time	90% of full scale: 3 to 10	90% of full scale: 3 to 10	90% of full scale: 3 to 10
Detection Indicator	Digital display of concentration; four alarm contacts; RS 232C interface	Digital readout; two alarm outputs	Digital readout; two alarm outputs for each channel
Power	110, 120, 220, 240 VAC	110, 120, 220, 240 VAC	110, 120, 220, 240 VAC
Battery Discharge Time, hr	N/A	N/A	N/A
Size (H x W x D, in.)	Rack unit: 7 x 19 x 16 Field/Packaged units: 17.5 x 17.25 x 10.6	6.6 x 17.2 x 11.4 and 6.6 x 17.2 x 12.7 (w/o and with condensation trap)	6.6 x 17.2 x 11.4 and 6.6 x 17.2 x 12.7 (w/o and with condensation trap)
Weight, lb	Rack unit: 40 Field unit: 60 Packaged systems: 70	20	20
Price	$9,000	$4,950	$7,200

Snap-On Tools Corporation

The ACT5550, ACT5555, and ACT5575 detectors are designed for pinpointing CFC-12 leaks in MACs. During the first quarter of 1993, Snap-On plans to release three new detectors for HFC-134a: ACT6550, ACT6560, and ACT6570. These three detectors parallel the CFC-12 series and have similar features.

Table B66. Snap-On Tools Corporation.

Parameter	Model		
	ACT5550	ACT5555	ACT5575
Description	Handheld, battery-operated detector for pinpointing leaks with 18-in. probe	Same as ACT5550 except that ACT5555 has pump and a coil cord between probe and case	Same as ACT5555 except that ACT5575 has an 8-segment LED bar graph and low battery LED
Sensor Technology	Negative corona discharge	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	CFC-12	CFC-12	CFC-12
Detection Limit	0.5 oz/yr	0.5 oz/yr	0.5 oz/yr
Response Time	"Instantaneous"	"Instantaneous"	"Instantaneous"
Detection Indicator	Indicating LED; audible alarm with variable "ticking" rate; earphone	Indicating LED; audible alarm with variable "ticking" rate; earphone	8-segment LED indicating bar graph; audible alarm with variable "ticking" rate
Power	9V battery	9V battery	9V battery
Battery Discharge Time, hr	15	12	12
Size (H x W x D, in.)	7.95 x 3.25 x 1.75	7.95 x 3.25 x 1.75	7.95 x 3.25 x 1.75
Weight, lb	0.8125	0.8125	0.8125
Price	$172	$120	$141

Technical Chemical Company

The Sercon Halogen Leak Detector (Part No. 8336) is sold for CFC-12, HCFC-22, HCFC-134a, and other refrigerants. The battery-operated detector has a 2-year warranty. An extender sensing tip, Part No. 8337, is also available. The detector uses a negative corona discharge sensor.

Table B67. Technical Chemical Company.

Parameter	Model: Sercon Halogen Leak Detector, Part No. 8336
Description	Handheld, battery-powered leak detector
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC
Detection Limit	0.5 oz/yr
Response Time	"Instantaneous"
Detection Indicator	LED and variable-frequency audible alarms
Power	9V alkaline battery
Battery Discharge Time, hr	10
Size (H x W x D, in.)	7 x 1.5 x 1.4
Weight, lb	0.375
Price	Detector: $108 Optional 6-in. extender probe: $21

The Trane Corporation

The Trane Refrigerant Monitor is a nondispersive IR instrument used for area monitoring for any refrigerant.

Table B68. The Trane Corporation.

Parameter	Model: Refrigerant Monitor
Description	NDIR instrument for area monitoring
Sensor Technology	Infrared
Application	Area monitoring
Refrigerants	All CFC, HCFC, HFC
Detection Limit	1 ppm
Response Time	
Detection Indicator	
Power	
Battery Discharge Time, hr	
Size (H x W x D, in.)	16 x 16 x 6.75
Weight, lb	
Price	$5,000

Thermal Gas Systems, Inc.

The three Haloguard area monitors use solid state sensors. An IRGA accessory allows the Haloguard II to also operate as an IR-based detector.

Table B69. Thermal Gas Systems, Inc.

Parameter	Model		
	Haloguard	Haloguard 10	Haloguard II
Description	Single-channel area monitor with solid state sensor	Ten-channel area monitor with solid state sensors	Six-channel area monitor with IR, solid state, and electro-chemical sensors
Sensor Technology	Solid state	Solid state	Solid state infrared
Application	Area monitoring	Area monitoring	Area monitoring
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	Generally 50-100 ppm for CFCs; 10-30 ppm for HCFCs, and 20-50 ppm for HFCs	Generally 50-100 ppm for CFCs; 10-30 ppm for HCFCs, and 20-50 ppm for HFCs	For solid state, generally 50-100 ppm for CFCs; 10-30 ppm for HCFCs; 20-50 ppm for HFCs
Response Time	90% in 1 min	<1 min	<1 min
Detection Indicator	LED concentration display, flashing LED alarm, remote alarm relay, optional analog output	LED concentration display, flashing LED alarm, remote alarm relay, analog output	LCD concentration display, strobe and audible alarms, remote alarm relays, optional analog output
Power	115 VAC/12-24 VDC power supply with battery backup	115 VAC/18-24 VDC power supply	115/230 VAC with battery backup
Battery Discharge Time, hr	1 (backup)	1 (backup)	1 (backup) except for IR sensor
Size (H x W x D, in.)	8.25 x 4.5 x 2.25	7.125 x 8.375 x 5.875	7.125 x 8.375 x 5.875
Weight, lb	3	5	8
Price	$1,290 plus $38 for power supply	$1,750 plus $540/$675 for each sensor, $160/$200 for power supply	$1,635 plus $335 per sensor; $2,220 for IR sensor

TIF Instruments, Inc.

All of the TIF detectors are portable instruments with negative corona discharge sensors for pinpointing leaks. The instruments have a two-position switch for CFC/HCFC or HFC refrigerants. The H10A is AC-powered; the others are battery-powered.

Table B70. TIF Instruments, Inc. H10A and 5050 detectors.

Parameter	Model	
	TIF H10A	TIF 5050
Description	AC-powered portable with pump and switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency and light increases in intensity with increasing gas concentration	Battery-powered handheld portable with switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency with increasing gas concentration
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	Variable-intensity light in probe; variable-frequency audible signal	Variable-frequency audible signal
Power	110 or 220 VAC	3 VDC (two C-cell alkaline batteries)
Battery Discharge Time, hr	N/A	50
Size (H x W x D, in.)	8.5 x 4.5 x 2.6	8 x 3 x 1.8
Weight, lb	2.25	1.25
Price	$249.95	$159.95

Table B71. TIF Instruments, Inc. 5550 and 5650 detectors.

Parameter	Model	
	TIF 5550	TIF 5650
Description	Battery-powered handheld portable with pump and switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency with increasing gas concentration	Battery-powered handheld portable with pump and switch for detecting HFC or CFC/HCFC refrigerants; audible signal increases in frequency with increasing gas concentration; seven LED visual signals indicate leak size
Sensor Technology	Negative corona discharge	Negative corona discharge
Application	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	All CFC, HCFC, HFC
Detection Limit	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)	<0.40 oz/yr (as low as 0.1 oz/yr for some refrigerants, e.g. CFC-11, -12)
Response Time	"Instantaneous"	"Instantaneous"
Detection Indicator	Variable-frequency audible signal	LED and variable-frequency audible signals
Power	3 VDC (two C-cell alkaline batteries)	3 VDC (two C-cell alkaline batteries)
Battery Discharge Time, hr	50	50
Size (H x W x D, in.)	8 x 3 x 1.8	8 x 3 x 1.8
Weight, lb	1.25	1.25
Price	$199.95	$229.95

Universal Enterprises, Inc.

The handheld detector uses an acoustic pump to collect the sample and has an LED "on" indicator.

Table B72. Universal Enterprises, Inc.

Parameter	Model: RLD1
Description	Handheld battery-powered portable for pinpointing leaks
Sensor Technology	Negative corona discharge
Application	Pinpointing leaks
Refrigerants	CFC-11, -12; HCFC-22; R-500, -502
Detection Limit	0.5 oz/yr
Response Time	"Instantaneous"
Detection Indicator	Audible beep alarm
Power	Two C-cell batteries
Battery Discharge Time, hr	200
Size (H x W x D, in.)	9 x 2.25 x 1.5
Weight, lb	1.16
Price	$169

Vulcain Alarme, Inc.

The Vulcain detector can be used to monitor for a variety of gases, including refrigerants. The detector system consists of a central control unit connected with up to 32 remote metal oxide semiconductor sensor/transmitters. The instrument has two channels with up to 16 sensor/transmitters each. Each sensor/transmitter has a 4- to 40-mA output and can operate in a standalone mode without the control unit.

Table B73. Vulcain Alarme, Inc.

Parameter	Model: Polygas VA-201
Description	Control unit and up to 32 remote sensors
Sensor Technology	Solid state
Application	Area monitoring
Refrigerants	All CFC, HCFC, HFC
Detection Limit	100 ppm to 2000 ppm
Response Time	20 sec for 90%
Detection Indicator	Audible and visual alarms; LCD display of concentration; RS-232 port
Power	24 VAC
Battery Discharge Time, hr	N/A
Size (H x W x D, in.)	Controller: 8 x 10 x 2 Transmitter: 4 x 6 x 3
Weight, lb	Controller: 2 Transmitter: 1
Price	Controller: $200 Sensor/transmitter: $700 each

Yokogawa Corporation

The Yokogawa Corporation detectors use heated diode sensors. The sensor consists of a platinum heating coil (the anode), inside of which a platinum tube (the cathode) is suspended. The platinum tube is filled with a calcined mixture of aluminum oxide (Al_2O_3) and an alkali metal carbonate. The anode is heated to about 800 °C (1470 °F), and 100 to 200 volts DC is applied between the anode and the cathode. A resistor is connected to the platinum tube, and any current is detected as a voltage across this resistor. The temperature is stabilized by a thermal deflection plate surrounding the platinum coil. The structure of the sensor is illustrated in Figure B1.

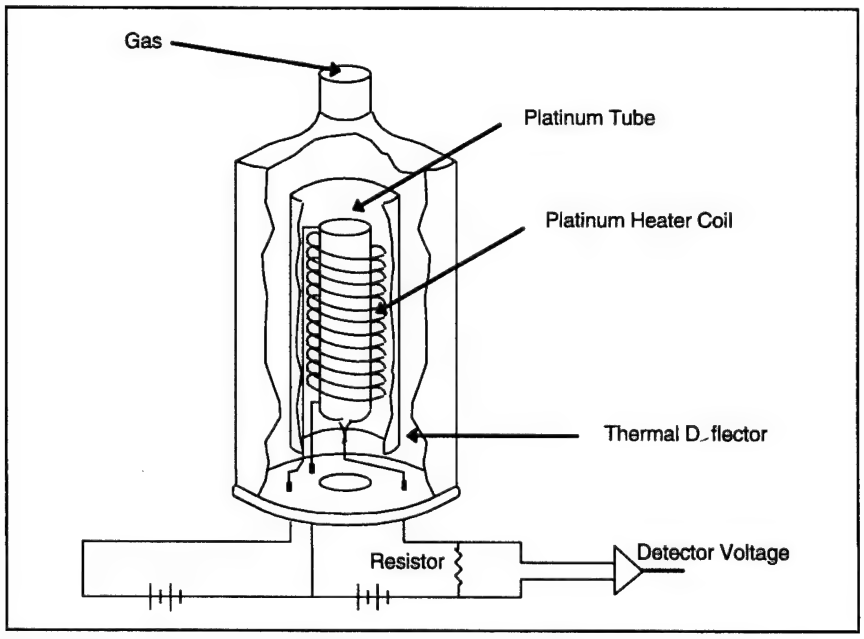

Figure B1. Structure of Yokogawa Corporation heated diode sensors.

Table B74. Yokogawa Corporation.

Parameter	Model		
	H10G	H10N	H25C
Description	Line-powered portable with internal air pump and built-in calibration reference	Battery-powered portable with internal air pump and built-in calibration reference	Line-powered industrial portable, self-calibrating with built-in 134a leak standard
Sensor Technology	Heated diode	Heated diode	Heated diode
Application	Pinpointing leaks	Pinpointing leaks	Pinpointing leaks
Refrigerants	All CFC, HCFC, HFC	Switch between CFC/HCFC and HFC	Switch between CFC/HCFC and HFC
Detection Limit	HFC-134a: 0.1 oz/yr CFC-12: 0.05 oz/yr	0.05 to 5 oz/yr	0.01 oz/yr
Response Time	<1 sec	<1 sec	<1 sec
Detection Indicator	Audible and probe light alarms	Audible and probe light alarms	Digital and analog display; audible and probe light alarms
Power	110 VAC (220 VAC optional)	12 VDC (with 12V battery clamp adapter, portable power pack, and auto cigarette lighter adapter) or 110 VAC	100/115 VAC (220/240 VAC optional)
Battery Discharge Time, hr	N/A	8	8
Size (H x W x D, in.)	4.5 x 8.5 x 2.75	5.75 x 8.5 x 3	8.25 x 5.5 x 14
Weight, lb	2	2	25
Price	$385	$399	$4,700

Appendix C: Other Detector Products by Manufacturer

Advanced Research Technologies, Inc.

Advanced Research Technologies produces a fluorescent leak detection additive to be used with alternative HFC refrigerants such as HFC-134a. The additive is dissolved in a polyalkene glycol (PAG) lubricant, used with HFC refrigerants. The material has passed the requirements of ANSI/ASHRAE Standard 97-1983. The company also markets fluorescent lights for use with the leak detector.

Amprobe Instrument

Amprobe Instrument's SoundSleuth ULD-100 battery-powered ultrasonic leak detector detects leaks to 0.6 oz/yr when the area is sprayed with water. Complete with headphones, the ULD-100 costs $157.85. An ultrasonic transmitter is also available. The TMULD-100 Testmaster Kit containing the ULD-100, transmitter, headphones, extensions, earphone, and case is available for $348.85.

Bright Solutions, Inc.

Bright Solutions markets battery-powered UV lamps to detect fluorescent tracers and leak-detection fluorescent dyes.

EnviroSystems Corporation

The Guardsman, manufactured by EnviroSystems Corporation, uses light refraction to detect the abnormal presence of vapor or gas in liquid lines, which would indicate a system leak. The sensor is mounted over a modified sight glass. A beam of light passes into the sight glass, is reflected off a polished surface, and is received at the sensor. Anything that passes through the beam is detected. Time delays and interface mechanisms are used to avoid false alarms. The interface mechanisms let the detector unit know which cycle the air-conditioning or refrigeration system is operating in; the detector will ignore the presence of gases if the system is in a cycle where gas is normal in the liquid line.

EPD Technology Corporation

The EPD-500S kit consists of the Ultrasonic Scanner, a rubber focusing probe, headset, battery recharger, video training program, operating manual, and carrying case. A meter showing increments of 0 to 100 gives intensity levels. The instrument operates on NiCad rechargeable batteries.

Goodway Tools

The Goodway ULD-90 Ultrasonic Leak Detector can locate leaks in both pressurized and nonpressurized systems. For nonpressurized systems and vessels (usually following construction), an ultrasonic transmitter is placed in the empty system, which is then scanned from the outside. The ULD-90 with headphones, scanning probe, contact probe, ultrasonic transmitter, and carrying case costs $995.

H.B. Fuller Co.

H.B. Fuller's Tracer Products Group makes a fluorescent leak detection kit (TP-1430) with a 12V lamp and an assortment of leak detection dyes.

Highside Chemicals, Inc.

Highside manufactures Trax liquid leak detectors.

Hoke, Inc.

Hoke sells two types of Leak Detective bubble forming solutions: Type I for use at 27 °F to 200 °F (-3 °C to 91 °C) and Type II for -65 °F to 200 °F (53 °C to 91 °C).

LA-CO Industries, Inc.

LA-CO Industries' Visu-Glow and Sure-Chek leak detectors are fluorescent bubble-forming solutions for external application. Visu-Glow is a high-viscosity solution; Sure-Chek is applied as a spray. Neither should be used on oxygen systems.

National Draeger, Inc.

National Draeger's 100/a is a very recently developed detector tube for measuring CFC concentrations. The 100/a consists of two separate tubes connected by shrinkage tubing. The first tube contains pyrophoric iron, which reacts with oxygen when the tips are broken off and ambient air is pumped through. The exothermic reaction heats any CFCs, which are pyrolyzed to give hydrogen chloride gas. The hydrogen chloride reacts with material in the second tube, giving a color change. Calibrations are available for CFC-11, CFC-113, and CFC-114. Other calibrations are being developed. The Draeger CFC detector differs from the Sensidyne CFC detector tubes, which use a separate pyrolysis apparatus.

Ridge Tool Company

Ridge Tool Company markets a line of fluorescent leak detection equipment. The model RLD-1000 and RLD-1100 SystemSafe leak detection kits include a lamp, UV goggles, adapter, and carrying case. The Model RLD-1000 kit also includes an injector and fluid; the RLD-1100 uses prefilled, premeasured capsules of leak detection fluid. Individual kit components and dyes are also available.

Refrigeration Technologies

The Big Blu bubble-forming solutions produced by Refrigeration Technologies are claimed to detect leaks down to 0.65 oz/yr. Refrigeration Technologies has published two thorough reports on pinpointing leaks (Pastorello, 1991 and Refrigeration Technologies, 1992).

Ritchie Engineering Company, Inc.

The Ritchie Yellow Jacket Fluorescent Leak Scanner System II uses disposable pre-filled solution injector tubes that can be connected directly to the system to inject fluorescent dye.

Robinair Division, SPX Corporation

Robinair will soon be commercializing an in-system fluorescent dye for pinpointing refrigerant leaks.

Sensidyne, Inc.

Sensidyne markets three detector tubes that sense the presence of hydrogen chloride gases released during pyrolysis of refrigerant gases: the +51, +51H (high range), and +51L (low range). The tubes require the use of separate pyrolyzer, which screws onto a hand-operated pump. Calibrations are available for CFC-11, CFC-12, HCFC-22, CFC-113, and CFC-114.

Spectronics Corporation

Spectronics Corporation supplies a variety of detector solutions and equipment for refrigerant leak detection using fluorescence. The Glo-Stick capsules are prefilled with fluorescent additives. The company also produces special formulations for HFC-134a with PAG and ester lubricants.

Stewart-Hall Chemical Corp.

Stuart-Hall manufactures two bubble-forming leak detection solutions, which are polymeric to increase the bubble lifetime. The Teltale Plus liquid will not freeze above 28 °F; Teltale Zero Freeze will not freeze above 0 °F.

Superior Signal Co.

Superior Signal manufactures two ultrasonic leak detectors—the AccuTrak VPX (and the waterproof VPX-WR version) and the lower-cost AccuTrak VPE. The prices are VPX: $1095; VPX-WE: $1600; VPE: $189. All of the kits contain a sound generator; the VPX kits also include a wave guide, horn restrictor, and AC and DC adapters.

TIF Instruments, Inc.

The TIF6500 Leak Detector can be combined with the TIF6501 Transmitter. Both components operate on a 9V battery. The leak detector, with a 12-in. probe, gives a beeping noise when leaks are approached.

UE Systems, Inc.

The UE Systems Ultraprobe 2000 has frequency tuning. This allows the operator to select the specific frequency of a problem sound and reduce interfering sound signals. The output is displayed on an analog meter; either a linear or logarithmic scale can be selected. The sensitivity allows detection of leaks down to 10^{-3} cm^3/sec (about 6 oz/yr).

Uniweld Products, Inc.

Uniweld Products sells a leak detector and components that detect halogen-containing refrigerants by the interaction of refrigerants with a copper reactor plate in a propane flame.

UVP, Inc.

The UVP Reveal A-670 fluorescent leak detector is marketed primarily for the automotive sector. The dye is compatible with napthene- and paraffin-based lubricants used with CFC-12 and is sold in 0.25-oz, single-dose bottles. UVP is now developing a fluorescent additive for PAG lubricants used with HFC-134a. The company also markets a variety of UV lamps for use with the fluorescent dye.

Wagner Products Corporation

Wagner markets three types of bubble-forming solutions: a fluorescent yellow, high viscosity fluid in a spray bottle (PRO-2000); a fluorescent, low-temperature solution (Radiant Leak-Finder); and a liquid leak detector with brush-on applicator (Leak-Finder). The PRO-2000 and Leak-Finder products meet military specifications for use with oxygen and compressed gases. The AudioTech Probe is a portable battery-powered diagnostic listening tool for detecting and amplifying noise from refrigerant leaks and other noise sources.

Watsco Components, Inc.

In addition to Search brand bubble-forming chemical leak detectors (one of which is fluorescent), Watsco manufactures RLM-1 and RLM-2 float-type refrigerant loss monitors. The monitors are attached to the liquid line immediately upstream of the expansion device. During normal operation, the monitor fills with liquid (sub-cooled) refrigerant, causing the float to rise and the switch to open. If a leak or other system malfunction decreases the amount of liquid refrigerant, the float drops and a switch closes. The monitor can be attached to an Alarm/Time Delay module (ATD-1). The time delay allows time for liquid to be produced upon startup following shutdown of the system compressor.

White Industries

White Industries sells a variety of fluorescent tracer dye products under the Fluoro-Lite tradename, including a fluorescent tracer dye (07840 and 07830), UV lamp and lamp kit (07200 and 07220), and a refrigerant dye injector (01510). The 07290 kit contains all of the above components.

Appendix D: Companies Contacted

ELECTRONIC DETECTOR MANUFACTURERS	
A. Abercrombe 128 S. Adams Hinsdale, IL 60521 Tele: 1-708-654-4954	A. W. Sperry Instruments, Inc. Attn: Dennis W. Carroll 245 Marcus Boulevard Hauppauge, NY 11788 Tele: 1-516-231-7050 Fax: 1-516-434-3128
A.D.D.M. International, Inc. Attn: Ami Gesser P.O. Box 572 Oceanside, NY 11572 Tele: 1-516-766-5997 Fax: 1-516-678-0259	Accura Flow Products Co., Inc. P.O. Box 100 Warminster, PA 18974-0100 Tele: 1-215-674-4782 Fax: 1-215-674-4784
Acme Engineering Products, Inc. Attn: G. S. Presser Trimex Industrial Building Route 11 Mooers, NY 12958 Tele: 1-518-236-5659 Fax: 1-518-236-6941	Adams Manufacturing Company 9790 Midwest Avenue Cleveland, OH 44125 Tele: 1-216-587-6801 Fax: 1-216-587-6807
Adsistor Technology, Inc. Attn: Patrick M. Dolan P.O. Box 51160 Seattle, WA 98115 Tele: 1-206-368-9110 Fax: 1-206-363-8271	Advanced Research Technologies, Inc. Attn: Terrence D. Kalley P.O. Box 33111 Bloomfield Hills, MI 48303-3111 Tele: 1-313-641-9332 Fax: 1-313-641-1716
AIM Safety Company, Inc. 1600 Derwent Way, No. 7 New Westminster, BC V3M 6M5 CANADA Tele: 1-800-275-4246 Fax: 1-604-522-2855	AIM USA 12919 Southwest Freeway, Suite 146 P.O. Box 720540 Stafford, TX 77477 Tele: 1-713-240-5020 Fax: 1-713-240-5022

AIM USA Attn: Perette K. Lee P.O. Box 770540 Houston, TX 77272-0540 Tele: 1-713-240-5020 Fax: 1-713-240-5022	Air Instruments & Measurements, Inc. 515 West Colorado Street Glendale, CA 91204 Tele: 1-818-247-7601 Fax: 1-818-247-7614
Air Instruments & Measurements, Inc. 13111 Brooks Drive, Suite D Baldwin Park, CA 91706 Tele: 1-818-813-1460	Airflow Technical Products Inc. 23 Railroad Avenue Netcong, NJ 07857 Tele: 1-800-247-8887 Fax: 1-201-691-4703
Airserco Manufacturing Co., Inc. P.O. Box 1415 Dayton, OH 45401 Tele: 1-513-461-1754 Fax: 1-513-461-1772	Alliance for Photonic Technology Attn: Peter Lathan 851 University Boulivard, SE Albuquerque, NM 87106-4339 Tele: 1-505-272-7004 Fax: 1-505-272-7000
Allied Signal, Inc. 101 Columbia Road P.O. Box 2245 Morristown, NJ 07962 Tele: 1-201-455-2000	Altech Controls 1545 Industrial Drive Missouri City, TX 77489 Tele: 1-713-499-5697
Altech Systems Corporation 441 Smithfield Street Pittsburgh, PA 15222 Tele: 1-412-562-7009 Fax: 1-412-562-7617	American Composite Technology 306 Northern Avenue Boston, MA 02210 Tele: 1-617-426-4142 Fax: 1-617-426-4892
American Gas & Chemical Co., Ltd. Attn: Dorothy Hampton 220 Pegasus Ave. Northvale, NJ 07647 Tele: 1-201-767-7300 Fax: 1-201-767-1741	American Gauge Corporation Attn: Kevin D. York P.O. Box 219 132 St. Martin Drive Suwanee, GA 30174 Tele: 1-404-932-0550 Fax: 1-404-932-0555
Ametek, Inc. Mansfield & Green Division 8600 Somerset Drive Largo, FL 34643 Tele: 1-813-536-7831 Fax: 1-813-539-6882	Ametek, Inc. Process & Analytical Instruments Division P.O. Box 9209 Newark, DE 19714-9209 Tele: 1-302-456-4400 Fax: 1-302-456-4444

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Fax: 1-412-826-0399

Amprobe Instrument
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Lynbrook, NY 11563
Tele: 1-516-593-5600
Fax: 1-516-593-5682

Analytical Development Company Ltd.
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Fax: 011-44-992-444567

Andersen Instruments, Inc.
4801 Fulton Industrial Boulevard
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Tele: 1-404-691-1910
Fax: 1-404-691-6315

Applied Science Corp.
P.O. Box 16118
Tampa, FL 33687
Tele: 1-813-988-3196
Fax: 1-813-988-2814

Astro International Corporation
100 Park Avenue
League City, TX 77573
Tele: 1-713-332-2484
Fax: 1-713-554-6795

Atlantic Chemical & Equipment Co.
2190 DeFoor Hills Road, NW
Atlanta, GA 30318
Tele: 1-404-355-5522
Fax: 1-404-355-8900

Ametek, Inc.
U.S. Gauge Division
900 Clymer Avenue
Sellersville, PA 18960
Tele: 1-215-257-6531
Fax: 1-215-257-4711

Anacon Corporation
117 South Street
Hopkinton, MA 01748
Tele: 1-508-435-6973
Fax: 1-508-435-6677

Anarad, Inc.
P.O. Box 3160
Santa Barbara, CA 93105
Tele: 1-805-963-6583
Fax: 1-805-962-4627

Antek Instruments, Inc.
Attn: Rudy Haas
300 Bammel Westfield Road
Houston, TX 77090
Tele: 1-713-580-0339
Fax: 1-713-580-0719

Arizona Instrument
1100 E. University Drive
P.O. Box 1930
Tempe, AZ 85280
Tele: 1-602-741-3400
Fax: 1-602-731-3434

ATD Tools
Attn: Joel Levin
114 I-70 Trade Center Drive
Saint Peters, MO 63376
Tele: 1-314-272-9050
Fax: 1-314-272-9044

Atlantic Ultraviolet Corporation
250 N. Fehr Way
Bay Shore, NY 11706
Tele: 1-516-586-5900
Fax: 1-516-595-2609

B&W Technologies Ltd 242, 3030-3 Avenue N.E. Calgary, AB T2A 6T7 CANADA Tele: 1-403-248-9226 Fax: 1-403-273-3708	Babcock & Wilcox Company P.O. Box 351 Barberton, OH 44203-0351 Tele: 1-216-860-2769 Fax: 1-216-860-1886
Bacharach, Inc. Attn: William P. Spohn 625 Alpha Drive Pittsburgh, PA 15238-2878 Tele: 1-412-963-2157 Fax: 1-412-963-2091	Bailey Controls Co. 29801 Euclid Avenue Wickliffe, OH 44092 Tele: 1-216-585-8500 Fax: 1-216-585-8756
Balzers High Vacuum Products Division Attn: Everett S. McGinley 8 Sagamore Park Road Hudson, NH 03051 Tele: 1-603-889-6888 Fax: 1-603-889-8573	Bambeck Systems Inc. 1921 E. Carnegie Avenue Santa Ana, CA 92705 Tele: 1-714-250-3100 Fax: 1-714-757-1610
Barber-Colman Attn: Mark L. W. Rehwald 1354 Clifford Avenue P.O. Box 2940 Loves Park, IL 61132-2940 Tele: 1-815-637-3000 Fax: 1-815-637-5306	Barringer Research Ltd. 304 Carlingview Drive Rexdale, Ontario M9W 5G2 CANADA Tele: 1-416-675-3870 Fax: 1-416-675-3876
Bascom-Turner Instruments 111 Downey Street Norwood, MA 02062 Tele: 1-800-225-3298 Fax: 1-617-551-0283	Bear Automotive Service Equipment Co. 2855 James Dr. New Berlin, WI 53151 Tele: 1-800-558-5585 Fax: 1-414-786-2963
Big A TempControl Attn: Art Hobbs 100 South Royal Lane P.O. Box 1955 Coppell, TX 75019 Tele: 1-214-471-8000	Bionics Instrument Co., Ltd. Attn: Hirotaka Komiya 6-1254-2 Shimizu, Higashiyamato Tokyo 207 JAPAN Tele: 011-81-0425-61-4856 Fax: 011-81-0425-65-3950
Biosystems, Inc. 5 Brookside Road Middlefield, CT 06455 Tele: 1-203-344-1079 Fax: 1-203-344-1068	Bomen/Hartmann & Braun 450 Ave. St. Jean-Baptiste Quebec City, Quebec G2E 5S5 CANADA Tele: 1-418-877-2944 Fax: 1-418-877-2834

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BRK Electronics Division
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Brooks Instrument
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Hatfield, PA 19440
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Fax: 1-215-362-3745

Brownell Electro, Inc.
Instrument & Control Division
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Tele: 1-800-922-0602
Fax: 1-201-287-6819

Brüel & Kjaer Instruments, Inc.
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Marlborough, MA 01752
Tele: 1-508-481-7000
Fax: 1-508-481-0519

Canadian General Filters Ltd.
39 Crockford Blvd.
Scarborough, ON M1R 3B7
CANADA
Tele: 1-416-757-3691
Fax: 1-416-757-4687

Capital Controls Company, Inc.
3000 Advance Lane
P.O. Box 211
Colmar, PA 18915
Tele: 1-800-523-2553
Fax: 1-215-822-8640

CCI Controls
Attn: Robert Flegal
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Tele: 1-213-560-6060
Fax: 1-213-560-1136

CEA Instruments, Inc.
Attn: Martin H. Adelman
16 Chestnut Street
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Tele: 1-201-967-5660
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Centurion Instrument Corporation
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Cerametec, Inc.
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Chestec, Inc.
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Fax: 1-516-883-7155

CI Systems, Inc.
4 Skyline Drive
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Tele: 1-914-592-1596
Fax: 1-914-592-2176

Cincinnati Test Systems, Inc. 5555 Dry Fork Road Village of Cleves, OH 45002 Tele: 1-513-367-6699	City Technology Ltd. City Technology Centre, Walton Road Portsmouth, Hampshire PO6 1SZ UNITED KINGDOM Tele: 011-44-70-532-5511 Fax: 011-44-70-538-6611
CMS Research Corporation 1075 South 13th Street, Suite 205 Birmingham, AL 35205 Tele: 1-205-934-1037	Cole-Parmer Instrument Company 7425 North Oak Park Avenue Chicago, IL 60648 Tele: 1-708-647-7600 Fax: 1-708-647-9660
Colette Electric Company 15024 Harper Detroit, MI 48224 Tele: 1-313-372-2200	Columbia Scientific Industries Corporation P.O. Box 203190 Austin, TX 78720 Tele: 1-512-258-5191 Fax: 1-512-258-5003
Columbus Instruments International Corp. 950 N. Hague Avenue Columbus, OH 43204 Tele: 1-614-488-6176 Fax: 1-614-276-0529	Computer Process Controls, Inc. 1275 Kennestone Circle, Suite 100 Marietta, GA 30066 Tele: 1-404-425-2724 Fax: 1-404-425-9319
ComStar International, Inc., I.P.C. Div. 20-45 128th Street College Point, NY 11356 Tele: 1-800-328-0142 Fax: 1-718-353-5998	Concept Technology, Inc. 408 Chez Paree Drive Hazelwood, MO 63042 Tele: 1-314-837-6002 Fax: 1-314-837-6385
Connecticut Analytical Corp. 70 Raton Drive Milford, CT 06460 Tele: 1-800-836-1028 Fax: 1-203-876-8513	Contempo Engineering Co. 553 Constitution Ave. Camarillo, CA 93010 Tele: 1-805-484-7715 Fax: 1-805-987-4048
Control Instruments Corporation 25 Law Drive Fairfield, NJ 07004-3295 Tele: 1-201-575-9114 Fax: 1-201-575-0013	Cosa Instrument Corp. 55 Oak Street Norwood, NJ 07648 Tele: 1-201-767-6600 Fax: 1-201-767-6804
Cosmos Gas Detection Products c/o Sam Dick Industries Attn: Stuart Bunstock 1140 N.W. 46th Street P.O. Box 70498 Seattle, WA 98107 Tele: 1-206-789-5410 Fax: 1-206-789-5414	CPS Products, Inc. Attn: Mark Grandholm 1010 East 31st Street Hialeah, FL 33013 Tele: 1-305-687-4121 Fax: 1-305-687-3743

Cuda Products Corporation Fiber Optic Division 6000 Powers Avenue Jacksonville, FL 32217 Tele: 1-904-737-7611 Fax: 1-904-733-4832	Custom Sensors & Technology 7534 Watson Road St. Louis, MO 63119 Tele: 1-314-962-4555 Fax: 1-314-962-4385
Danfoss Automatic Controls Attn: Steve Gugliotta 4971 Mercantile Road Baltimore, MD 21236 Tele: 1-410-931-8250 Fax: 1-410-931-8256	Danhard, Inc. 3839 Dilido Road Dallas, TX 75228 Tele: 1-214-328-8541 Fax: 1-214-320-0965
Dasibi Environmental Corporation 515 West Colorado Street Glendale, CA 91204 Tele: 1-818-247-7601	Datatest, Inc. 6850 Hibbs lane Levittown, PA 19057 Tele: 1-215-943-0668 Fax: 1-215-547-7973
Davis Instrument Manufacturing Co., Inc. 4701 Mt. Hope Drive Baltimore, MD 21215-9947 Tele: 1-800-548-9409 Fax: 1-410-358-0252	Delphian Corp. 220 Pegasus Ave. Northvale, NJ 07647 Tele: 1-800-526-1008 Fax: 1-201-767-1741
Delta F Corporation 4 Constitution Way Woburn, MA 01801-9868 Tele: 1-617-935-4600 Fax: 1-617-938-0531	Detcon, Inc. P.O. Box 8067 The Woodlands, TX 77387-8067 Tele: 1-713-367-4100 Fax: 1-713-292-2860
Detector Electronics Corporation 6901 West 110th Street Minneapolis, MN 55438 Tele: 1-612-941-5665 Fax: 1-612-829-8750	Direct Safety Company 7815 S. 46th Street Phoenix, AZ 85044 Tele: 1-800-528-7405
Dylon Industries, Inc. 7700 Clinton Road Cleveland, OH 44144 Tele: 1-216-651-1300 Fax: 1-216-651-1777	Dynamation, Inc. Attn: Scott C. Stivers 3784 Plaza Drive Ann Arbor, MI 48108 Tele: 1-313-769-0573 Fax: 1-313-769-1888
E. Vernon Hill, Inc. #5 3rd Street #1216 San Francisco, CA 94103 Tele: 1-415-543-0268 Fax: 1-415-543-8106	Eagle Creek Technology Attn: John Dulaney 6666 E. 75th Street, Suite 500 Indianapolis, IN 46250 Tele: 1-317-594-9069 Fax: 1-317-849-2435

Eco-Dyne Attn: L. Michael Mayers, Jr. 2590 West 2nd Avenue Denver, CO 80219 Tele: 1-303-727-9000 Fax: 1-303-727-9049	EDA Controls Corp. 7020 Huntley Road Columbus, OH 43229 Tele: 1-614-431-0694
Edwards High Vacuum International Manor Royal Crawley West Sussex RH10 2LW England Tele: 011-44-293-28844 Fax: 011-44-293-33453	EEV, Inc. Attn: Charles Settens 4 Westchester Plaza Elmsford, NY 10523-0482 Tele: 1-914-592-6050 Fax: 1-914-682-8922
EIT Exidyne Instrumentation Technologies 251 Welsh Pool Road Exton, PA 19341 Tele: 1-215-363-5450 Fax: 1-215-363-0167	Elcon Instruments, Inc. 137 Gibralter Street Annapolis, MD 21401 Tele: 1-410-280-6686 Fax: 1-410-263-5790
Electro Optical Industries, Inc. Attn: Joe Lansing 859 Ward Drive Santa Barbara, CA 93111 Tele: 1-805-964-6701 Fax: 1-805-967-8590	Elf Atochem Sensors, Inc. 950 Forge Avenue Norristown, PA 19403 Tele: 1-215-666-3500 Fax: 1-215-666-3509
Eltec Instruments, Inc. Attn: David Cima P.O. Box 9610 Daytona Beach, FL 32120-9610 Tele: 1-800-874-7780 Fax: 1-904-258-3791	EMCO Technologies, Inc. 56 State Street Box 363 Holley, NY 14470 Tele: 1-716-638-5990 Fax: 1-716-638-5878
Encore Controls, Inc. Attn: Brett Hendricks 910 Kennesaw Mtn. Industrial Pkwy., Suite 200 Marietta, GA 30060 Tele: 1-404-427-9811	ENMET Corporation Attn: Elwood J. Boomus 680 Fairfield Court P.O. Box 979 Ann Arbor, MI 48106-0979 Tele: 1-313-761-1270 Fax: 1-313-761-3220
Environmental Technologies Group, Inc. Attn: Richard Priddy 1400 Taylor Avenue P.O. Box 9840 Baltimore, MD 21284-9840 Tele: 1-800-635-4598 Fax: 1-410-321-5255	EnviroSystems Corporation Attn: Jerry Justice 6000 Creek Road, Suite 100 Cincinnati, OH 45242 Tele: 1-513-984-2404 Fax: 1-513-984-2932

EPD Technology Corporation
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12 West Main Street
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EPM Environmental
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Eppendorf North America, Inc.
545 Science Drive
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Euramark
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P.O. Box 823
Mount Prospect, IL 60056
Tele: 1-708-255-1917
Fax: 1-708-255-1959

Everco Industries
A Moog Automotive Company
Attn: Alan Woll
6565 Wells Avenue
St. Louis, MO 63133
Tele: 1-314-385-3400
Fax: 1-314-679-6983

Extrel Mass Spectrometry
Attn: Joseph J. Schwab
575 Epsilon Drive
Pittsburgh, PA 15238
Tele: 1-412-963-7530
Fax: 1-412-963-6578

Factory Air
Attn: Art Hobbs
100 South Royal Lane
P.O. Box 1955
Coppell, TX 75019
Tele: 1-214-471-8000

Factory Auto Air Conditioning
2014 17th Street
Saratosa, FL 34234
Tele: 1-813-957-4855

FasTest, Inc.
1005 Westgate Drive
Saint Paul, MN 55114
Tele: 1-612-645-6266
Fax: 1-612-645-6938

Figaro USA, Inc.
Attn: Ed Godziszewski
1000 Skokie Blvd, Suite 575
Wilmette, IL 60091
Tele: 1-708-256-3546
Fax: 1-708-256-3884

Fischer & Porter Company
125 East County Line Road
Warminster, PA 18974
Tele: 1-215-674-6000
Fax: 1-215-674-7181

Fluid Data, Inc.
2512 N. Velasco
Angleton, TX 77515
Tele: 1-409-849-2344

Ford Motor Company
Rotunda Equipment Department
Attn: Stan Svoboda
300 Renaissance Center
P.O. Box 43396
Detroit, MI 48243
Tele: 1-313-446-8458
Fax: 1-313-446-8456

Four Seasons
Division of Standard Motor Products, Inc.
Attn: Art Hobbs
100 South Royal Lane
P.O. Box 1955
Coppell, TX 75019
Tele: 1-214-471-8000

The Foxboro Company Attn: Paula S. Keefe 600 North Bedford Street P.O. Box 500 East Bridgewater, MA 02333 Tele: 1-508-378-5400 Fax: 1-508-378-5505	G.C. Instruments 49050 Milmont Drive Fremont, CA 94538 Tele: 1-510-226-1329 Fax: 1-510-226-1112
Gas Tech, Inc. Attn: John Villalovos 8407 Central Avenue Newark, CA 94560-3431 Tele: 1-510-794-6200 Fax: 1-510-794-6201	Gem Products, Inc. Attn: Mike LeProhon 12472 Edison Way Garden Grove, CA 92641 Tele: 1-714-372-9650 Fax: 1-714-897-1012
Gemini Detectors, Inc. 1016 Hercules Houston, TX 77058 Tele: 1-713-488-1541 Fax: 1-713-486-9207	Genelco Division of Bindicator Company Attn: Ed Dunkelberger 1915 Dove Street P.O. Box 610286 Port Huron, MI 48061-0286 Tele: 1-313-987-2700 Fax: 1-313-987-4476 Tele: 1-800-626-2000
General Analysis Corporation Attn: Douglas A. Friedman 140 Water Street Box 528 South Norwalk, CT 06856-0528 Tele: 1-203-852-8999 Fax: 1-203-838-1551	General Monitors Attn: Robert Wek 26776 Simpatica Circle El Toro, CA 92630-9914 Tele: 1-714-581-4464 Fax: 1-714-581-1151
Genesis International Inc. Attn: John A. Blank 1605 Manufacturers Drive Fenton, MO 63026 Tele: 1-314-343-0011 Fax: 1-314-343-0472	Geopal System A/S Attn: Georg Jorgensen Tranemosevej 30 DK-2750 Ballerup, Copenhagen DENMARK Tele: 011-45-4-297-0035 Fax: 011-45-4-468-2305
GfG America Gas Detection, Ltd. 8300 Manchester Road Saint Louis, MO 63144 Tele: 1-314-961-6665 Fax: 1-314-961-9166	GfG Gas Electronics, Inc. 6617 Clayton Rd., No. 209 Clayton, MO 63117 Tele: 1-800-783-9523

Goodway Tools Corporation
420 West Avenue
Stamford, CT 06902-6384
Tele: 1-203-359-4708
Fax: 1-203-359-9601

Goss, Inc.
Route 8
P.O. Box 57
Glenshaw, PA 15116
Tele: 1-800-300-4677
Fax: 1-412-486-6844

GOW-MAC Instrument Company
Attn: Dr. Albert S. Tenney III
P.O. Box 32
Bound Brook, NJ 08805-0032
Tele: 1-908-560-0600
Fax: 1-908-271-2782

Grace Industries, Inc.
Box 167
Transfer, PA 16154
Tele: 1-412-962-9231

Grainger Division
W. W. Grainger, Inc.
333 Knightsbridge Parkway
Lincolnshire, IL 60069
Tele: 1-708-913-8333
Fax: 1-708-913-7391

H.B. Fuller Co.
Tracer Products Group
3530 North Lexington Avenue
St. Paul, MN 55126
Tele: 1-612-481-1588
Fax: 1-612-486-0948

H.T. Controls
1605 Manufacturers Drive
Fenton, MO 63026
Tele: 1-314-343-0011
Fax: 1-314-343-0472

Han-Power Technologies, Inc.
P.O. Box 84-415
Taipei
TAIWAN
Tele: 011-886-2-3964049
Fax: 011-886-2-3972854

Heads Up! Products Co.
23 N. Gore Avenue, No. 002
Saint Louis, MO 63119-2300
Tele: 1-800-548-2117
Fax: 1-314-961-0436

Heath Consultants
100 Tosca Drive
P.O. Box 9114
Stoughton, MA 02072-9114
Tele: 1-800-432-8487
Fax: 1-617-341-4359

Hemco Corporation
111 North Powell
Independence, MO 64056
Tele: 1-816-796-2900
Fax: 1-816-796-3333

Henderson Engineering
Sahara Air Dryer Division
95 North Main
Sandwich, IL 60548
Tele: 1-815-786-9471
Fax: 1-815-786-6117

Hercules Chemical Company, Inc.
29 W. 38 Street
New York, NY 10018
Tele: 1-212-869-4330
Fax: 1-800-333-3456

Highside Chemicals, Inc.
P.O. Box 3748
Gulfport, MS 39505
Tele: 1-601-896-9220
Fax: 1-601-896-9544

Hitech Instruments Attn: Glenn R. Reddington 40 McLean Road Brevard, NC 28712 Tele: 1-800-327-8665 Fax: 1-704-884-9719	HNU Systems, Inc. 160 Charlemont Street Newton, MA 02161-9987 Tele: 1-617-964-6690 Fax: 1-617-558-0056
Hoke, Inc. One Tenakill Park Cresskill, NJ 07626 Tele: 1-201-568-9100 Fax: 1-201-568-5913	Horiba Instruments, Inc. 1021 Duryea Avenue Irvine, CA 92714 Tele: 1-714-250-4811 Fax: 1-714-250-0924
IMO Industries, Inc. Gems Sensors Division Attn: Mark Zabawa 1 Cowles Road Plainville, CT 06062 Tele: 1-203-747-3000 Fax: 1-203-747-4244	Imperial Eastman Attn: Trent Rhoads 6300 West Howard Street Niles, IL 60714-3492 Tele: 1-708-967-4500 Fax: 1-708-967-6383
Industrial Instruments and Supplies P.O. Box 416 12 Countyline Industrial Park Southampton, PA 18966 Tele: 1-800-523-6079	Industrial Safety & Security Co. 1386 Neubrecht Lima, OH 45801 Tele: 1-419-227-6030
Industrial Scientific Corporation 1001 Oakdale Road Oakdale, PA 15071 Tele: 1-800-338-3287 Fax: 1-412-788-8353	Infrared Analysis, Inc. Attn: Steven T. Hanst 1424 N. Central Park Avenue Anaheim, CA 92802 Tele: 1-714-535-7667 Fax: 1-714-535-5046
Infrared Associates, Inc. 1002 Eastpark Blvd Cranbury, NJ 08512 Tele: 1-609-395-7600 Fax: 1-609-395-8700	Infrared Fiber Systems, Inc. Attn: George M. Hooley 2301-A Broadbirch Drive Silver Spring, MD 20904 Tele: 1-301-622-9546 Fax: 1-301-622-7135
Infrared Industries, Inc. 12151 Research Parkway Orlando, FL 32826 Tele: 1-407-282-7700 Fax: 1-407-273-9046	Infrared Instruments P.O. Box 989 Santa Barbara, CA 93102 Tele: 1-805-684-4181 Fax: 1-805-684-2517

Infrared Laboratories, Inc.
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Tucson, AZ 85719-6505
Tele: 1-602-622-7074
Fax: 1-602-623-0765

Infrared of NJ
River Street Station
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Paterson, NJ 07544
Tele: 1-201-742-2247
Fax: 1-201-523-0375

Infrared, Inc.
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Parlin, NJ 08859
Tele: 1-908-536-4455
Fax: 1-908-536-8935

INTEC Controls, Inc.
P.O. Box 12506
La Jolla, CA 92039
Tele: 1-619-268-4744
Fax: 1-619-268-3955

International Sensor Technology
Attn: Jack McCann
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Irvine, CA 92714
Tele: 1-714-863-9999
Fax: 1-714-474-7417

Interscan Corp.
P.O. Box 2496
Chatsworth, CA 91313-2496
Tele: 1-800-458-6153
Fax: 1-818-341-0642

InterTech Development Company
7401 N. Linder Avenue
Skokie, IL 60077
Tele: 1-708-679-3377
Fax: 1-708-679-3391

Inventron, Inc.
23630 Industrial Park Drive
Farmington Hills, MI 48024
Tele: 1-313-473-9250
Fax: 1-313-473-9255

Ion Track Instruments, Inc.
Attn: David Morris
340 Fordham Road
Wilmington, MA 01887
Tele: 1-508-658-3767
Fax: 1-508-657-5954

J and N Associates, Inc.
Attn: J. Scott Kleppe
P.O. Box 183
Wheeler, IN 46393
Tele: 1-219-759-1142
Fax: 1-219-759-1835

J.C. Whitlam Manufacturing Co.
200 W. Walnut Street
P.O. Box 71
Wadsworth, OH 44281
Tele: 1-800-321-8358
Fax: 1-216-334-3005

John M. Winslow Company
27496 Whitcomb
Livonia, MI 48154
Tele: 1-313-525-1470

Kaye Instruments, Inc.
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Bedford, MA 01730
Tele: 1-617-275-0300
Fax: 1-617-275-9024

Kobbe-McCawley Corp.
704 E. Columbus Ave.
P.O. Box 1437
Melbourne, FL 32902
Tele: 1-407-727-0876

LA-CO Industries, Inc.
Attn: John Mortensen
250 N. Washtenaw Avenue
Chicago, IL 60612
Tele: 1-312-826-1700
Fax: 1-312-826-7130

Lakewood Systems
9125 Grannis
Houston, TX 77075
Tele: 1-713-944-3140
Fax: 1-713-941-8469

Laser Science, Inc. 75 Chapel Street Newton, MA 02158 Tele: 1-617-969-2211 Fax: 1-617-969-3212	Lear Siegler Measurement Controls 74 Inverness Drive East Englewood, CO 80112 Tele: 1-303-792-3300 Fax: 1-303-799-4853
Leeds & Northrup Sumneytown Pike, P.O. Box 4 North Wales, PA 19454-0904 Tele: 1-215-699-2000 Fax: 1-215-699-3702	Lewis Energy Systems, Inc. 395 West 1100 North North Salt Lake, UT 84054 Tele: 1-801-292-0493 Fax: 1-801-292-9908
Leybold-Inficon, Inc. Attn: Jerry Wander 6500 Fly Road East Syracuse, NY 13057 Tele: 1-315-434-1100 Fax: 1-315-437-3803	Liebert Corp. 1050 Dearborn Drive P.O. Box 29186 Columbus, OH 43229 Tele: 1-614-888-0246 Fax: 1-614-841-6022
LIS Laser Imaging Systems 204-A E. McKenzie Street Punta Gorda, FL 33950 Tele: 1-813-639-3533 Fax: 1-813-639-6458	Lumenite Electronic Co. 2331 N. 17th Avenue Franklin Park, IL 60131 Tele: 1-708-455-1450 Fax: 1-708-455-0127
Lumidor Safety Products Attn: Kathy Hunt 11221 Interchange Circle South Miramar, FL 33025 Tele: 1-305-433-7000 Fax: 1-305-433-7730	Lumidor Safety Products 5364 N.W. 167 Street Miami, FL 33014 Tele: 1-305-625-6511
MAC Tools, Inc. Attn: William E. Green P.O. Box 370 Washington Court House, OH 43160 Tele: 1-800-848-6500 Fax: 1-614-333-2441	Macurco, Inc. Attn: James H. Currans 3946 South Mariposa Street Englewood, CO 80110 Tele: 1-303-781-4062 Fax: 1-303-761-6640
Magnetek 333 Route 46 Fairfield, NJ 07004 Tele: 1-201-227-7800 Fax: 1-201-882-2828	Manning Systems, Inc. 11511 W. 83rd Terrace Lenexa, KS 66214 Tele: 1-913-894-1185 Fax: 1-913-894-1296
Material Control, Inc. 338 E. Sullivan Rd. Aurora, IL 60504 Tele: 1-800-926-0376 Fax: 1-708-892-4931	Mateson Chemical Corporation Attn: Jean F. Mateson 1025 East Montgomery Avenue Philadelphia, PA 19125 Tele: 1-215-423-3200 Fax: 1-215-423-1164

Matheson Instruments
166 Keystone Road
Montgomeryville, PA 18936
Tele: 1-800-732-0340

Matheson Safety Products
Attn: Lloyd C. Kent
30 Seaview Drive
Secaucus, NJ 07096-1587
Tele: 1-201-867-4100
Fax: 1-201-867-4572

McNeill International, Inc.
Attn: Lillian McNeill
37914 Euclid Avenue
Willoughby, OH 44094
Tele: 1-800-626-3455
Fax: 1-216-953-1933

MDA Scientific, Inc.
405 Barclay Blvd.
Lincolnshire, IL 60069
Tele: 1-800-323-2000
Fax: 1-708-634-1371

Membrane Technology and Research, Inc.
Attn: Mr. Carlos Casillas
1360 Willow Road, Suite 103
Menlo Park, CA 94025-1516
Tele: 1-415-328-2228
Fax: 1-415-328-6580

Metrosonics, Inc.
General Products Division
P.O. Box 23075
Rochester, NY 14692
Tele: 1-716-334-7300
Fax: 1-716-334-2635

Micro Pneumatic Logic, Inc.
2890 N.W. 62nd Street
Fort Lauderdale, FL 33309-1786
Tele: 1-305-973-6166
Fax: 1-305-973-6339

Microsensor Systems, Inc.
62 Corporate Court
Bowling Green, KY 42103
Tele: 1-502-745-0099

Miles, Inc.
Compur Monitors
7015 W. Tidwell, Suite G106
Houston, TX 77092
Tele: 1-713-939-7007
Fax: 1-713-939-1103

Milton Roy
Cel Division
1885 N. Main Street
Orange, CA 92665
Tele: 1-714-283-3694

Milton Roy
Process & Environmental Instruments Division
1238 West Grove Avenue
Orange, CA 92665
Tele: 1-714-974-5560
Fax: 1-714-921-2531

Mine Safety Appliances Company
Instrument Division
Attn: Duane W. DeArmitt
P.O. Box 427
Pittsburgh, PA 15230
Tele: 1-800-672-4678
Fax: 1-412-776-3280

Mitchell Instrument Co.
1570 Cherokee St.
Can Marcos, CA 92069
Tele: 1-619-744-2690

Mitsubishi International Corporation
Shibaura Electronics Company
Non Ferrous Metal Division
520 Madison Avenue
New York, NY 10022
Tele: 1-212-605-2158
Fax: 1-212-308-4709

MKS Instruments, Inc. Six Shattuck Road Andover, MA 01810-2440 Tele: 1-508-975-2350 Fax: 1-508-975-0093	Motors & Armatures, Inc. P.O. Box 5550 Hauppauge, NY 11788 Tele: 1-516-348-0200
MTI Analytical Instruments 41762 Christy Street Freemont, CA 94538 Tele: 1-510-490-0900 Fax: 1-510-651-2498	Murray Temperature Control A Moog Automotive Company Attn: Alan Woll 6565 Wells Avenue St. Louis, MO 63133 Tele: 1-314-385-3400 Fax: 1-314-679-6983
Mycom Corporation Refrigeration Division 19475 Gramercy Place Torrance, CA 90501 Tele: 1-213-775-6322 Fax: 1-213-533-1540	NAPA Auto Parts 2999 Circle 75 Parkway Atlanta, GA 30339 Tele: 1-404-953-1700
National Draeger, Inc. Attn: Edward G. Ligus, Jr. 101 Technology Drive P.O. Box 120 Pittsburgh, PA 15230 Tele: 1-412-788-5610 Fax: 1-412-787-2207	National Refrigeration Products Attn: Michel Maniez 1950 Street Road, Suite 308 Bensalem, PA 19020 Tele: 1-215-639-5885 Fax: 1-215-639-5765
Neotronics North America, Inc. Attn: Geoff Smith 2144 Hilton Drive Gainesville, GA 30501 Tele: 1-800-535-0606 Fax: 1-404-352-9282	Nova Analytical Systems, Inc. 1925 Pine Avenue Niagara Falls, NY 14301 Tele: 1-716-285-0418
Nu-Calgon Wholesaler, Inc. 2451 Schuetz Road Maryland Heights, MO 63043 Tele: 1-314-994-1010 Fax: 1-800-554-5499	Nupro Company 4800 E. 345th Street Willoughby, OH 44094 Tele: 1-216-951-7100 Fax: 1-216-951-4872
Orbisphere Laboratories 70 Kinderkamack Rd. Emerson, NJ 07630 Tele: 1-201-265-4900	Ozone Research & Equipment Corporation Attn: Marshall L. Mallak 3840 North 40th Avenue Phoenix, AZ 85019 Tele: 1-602-272-2681 Fax: 1-602-272-4839

Pacer Industries, Inc.
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Panametrics, Inc.
221 Crescent Street
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Fax: 1-617-894-8582

Perkin-Elmer Corporation
Applied Science Division
2771 North Garey Avenue
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Tele: 1-714-593-3581
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Photovac International, Inc.
Attn: Joyce D. Austin
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Deer Park, NY 11729
Tele: 1-516-254-4199
Fax: 1-516-254-4284

Precisionaire, Inc.
P.O. Box 7568
Saint Petersburg, FL 33734
Tele: 1-813-822-4411

Quality Engineering Products Corp.
9400 N.W. 12 Street
Miami, FL 33172
Tele: 1-305-599-2222
Fax: 1-305-593-0069

Quatrosense Environmental Ltd.
5935 Ottawa Street
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PAMA Electronics Company Ltd.
Attn: Alex Rosenblum
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ISRAEL
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PCP, Inc.
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West Palm Beach, FL 33409-3287
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Fax: 1-407-683-0507

Perma-Pipe Division
Midwesco, Inc.
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Tele: 1-708-966-2235
Fax: 1-708-966-8563

pHOX Systems, Inc.
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4400 South Cedar Brook Road
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Fax: 1-215-366-0173

Promax Industries, Inc.
1930 S. Navajo Street
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Quantum Instruments Inc.
1075 Stewart Avenue
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Raychem Corporation
Commercial Construction Group
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Rectorseal Corporation 2830 Produce Row Houston, TX 77023 Tele: 1-713-928-6423 Fax: 1-713-928-2039	Refrigeration Technologies Attn: John Pastorello P.O. Box 3571 Fullerton, CA 92634 Tele: 1-800-869-1407 Fax: 1-714-526-4598
Regin HVAC Products, Inc. 26 Lafayette Street P.O. Box 2851 Stamford, CT 06906 Tele: 1-203-323-0115 Fax: 1-203-327-7295	Rel-Tek Corporation 616 Beatty Road Monroeville, PA 15146 Tele: 1-412-373-6700 Fax: 1-412-373-6703
Ricwil Piping Systems Division Intergy, Inc. 10100 Brecksville Road Brecksville, OH 44141 Tele: 1-216-526-1600 Fax: 1-216-526-3158	Ridge Tool Company Attn: Mark W. Downie 400 Clark Street Elyria, OH 44036 Tele: 1-216-329-3220 Fax: 1-216-4551
Ritchie Engineering Company, Inc. Attn: Tom Ritchie 10950 Hampshire Avenue South Bloomington, MN 55438-2391 Tele: 1-612-943-1333 Fax: 1-800-322-8684	Robinair Division Attn: Robert F. Allomong SPX Corporation 9 Robinair Way Montpelier, OH 43543-0193 Tele: 1-419-485-5561 Fax: 1-419-485-8300
Rosemont Analytical 600 S. Harbor Blvd. La Habra, CA 90631-6166 Tele: 1-310-690-7600	Rosemont Analytical, Inc. 1201 N. Main Street P.O. Drawer 901 Orrville, OH 44667 Tele: 1-800-628-1200, X658
Roxan, Inc. 5425 Lockhurst Woodland Hills, CA 91367 Tele: 1-818-703-6108 Fax: 1-818-341-0642	S.O.S. Products Co., Inc. Fourth & Railroad Street East Greenville, PA 18041 Tele: 1-215-679-6262
Safety Supply America Corp. One Civic Plaza Dr., Suite 320 Carson, CA 90745 Tele: 1-800-772-6733	Sauter Controls Corp. 330 Sunrise Highway Rockville Centre, NY 11570 Tele: 1-516-764-9006 Fax: 1-516-764-9094

Scott Aviation
Attn: A. L. Perry
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Scott Specialty Gases, Inc.
6141 Route 611
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Sensidyne, Inc.
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Sensor Electronics
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Sheldon Instruments
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Solidyne 1202 Carnegie Street Rolling Meadows, IL 60008 Tele: 1-708-394-3333 Fax: 1-708-394-8083	Solomat Attn: Richard T. Stonier The Waterside Building 26 Pearl Street Norwalk, CT 06850 Tele: 1-203-849-3111 Fax: 1-203-847-9320
Sonoxco, Inc. 430 Ferguson Dr., Bldg. 3 Mountain View, CA 94043 Tele: 1-415-960-3007	Spectra Gases, Inc. 277 Colt Street Irvington, NJ 07111 Tele: 1-800-932-0624
Spectrex Corporation 3580 Haven Avenue Redwood City, CA 94063 Tele: 1-415-365-6567 Fax: 1-415-365-5845	Spectrogon 550 County Avenue Secaucus, NJ 07094 Tele: 1-201-867-4888 Fax: 1-201-867-2191
Spectronics Corporation Attn: Gene Marrano 956 Brush Hollow Road P.O. Box 483 Westbury, NY 11590 Tele: 1-800-274-8888 Fax: 1-516-333-4859	Spirax Sarco, Inc. 1951 Glenwood Street S.W. P.O. Box 119 Allentown, PA 18105 Tele: 1-215-797-5830 Fax: 1-215-433-1346
Steveco Products White-Rodgers Division 9797 Reavis Road Saint Louis, MO 63123 Tele: 1-314-577-1300 Fax: 1-314-577-1517	Stewart-Hall Chemical Corporation Attn: Harvey Grodjesk 222 Washington Street Mount Vernon, NY 10553 Tele: 1-914-668-6300 Fax: 1-914-668-7862
Superior Signal Company, Inc. Attn: Paul B. Tashian P.O. Box 96 Spotswood, NJ 08884-9984 Tele: 1-908-251-0800 Fax: 1-908-251-9442	Technical Chemical Company Attn: Ronald E. Keith 10737 Spangler Road Dallas, TX 75220 Tele: 1-214-556-1421 Fax: 1-214-506-7493

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